SORGHUM QUALITY LABORATORY MANUAL FOR USE IN WEST AFRICA

Jeannette McLaughlin Shull
Moussa Oumarou
Allen W. Kirleis
John W. Clark

International Programs in Agriculture
Agricultural Administration Building
Purdue University
West Lafayette, Indiana 47907

Institut National de Recherches Agronomiques du Niger
(INRAN)
BP 429
Niamey, Niger

INTSORMIL
241 Keim Hall
East Campus
University of Nebraska
Lincoln, Nebraska 68583-0723

Supported by USAID contracts 683-0225, Niger Cereal Research Project (Purdue University, Alabama A&M University, L'Institut National de Recherches Agronomiques) and AID/DSAN/XII-G-0149, INTSORMIL Project.

Il exist également une édition francais de cette publication

A French edition of this publication exists

Jeannette McLaughlin Shull - U.S. Peace Corps/Purdue University/INTSORMIL
Moussa Oumarou - INRAN
Allen W. Kirleis - Purdue University/INTSORMIL
John W. Clark - NCRP

ACKNOWLEDEMENT

We wish to acknowledge the invaluable support from the agencies (Institut National de la Recherches Agronomique du Niger, INRAN; United States Peace Corps; Niger Cereal Research Project, NCRP; The Sorghum/Millet Collaborative Research Program, INTSORMIL and U.S. Agency for International Development, USAID) involved with the preparation of this food quality manual. Special thanks are extended to personnel associated with the Cereal Technology Laboratories in Niger (Daouda Moussa and Moussa Taweye-Laboratoire Qualité Cerealière, INRAN) and Mali (Mariam Haidara, Salimata Coulibaly and John Scheuring - La Cellule de Technologie Alimentair, SRCVO) for their on the ground testing of laboratory procedures and contribution of laboratory methodology to the manual. Appreciation is also extended to U.S. Peace Corps for providing the services of a trained food scientist (Jeannette McLaughlin Shull) to the INRAN Laboratoire Qualité Cerealière. It was during this 2 year service period that the first draft of the manual was written. We express sincere appreciation to Niger Cereal Research Project for continued encouragement and to USAID and INTSORMIL for funding support. We also acknowledge the technical advice provided by Drs. Suzanne Nielsen and Larry Butler, Purdue University, on the protein and tannin methodology preparation. Finally, we thank the staff of the Department of International Programs in Agriculture (Jan Coleman and Susan MacKay) and Food Science (Julie Watterson and Annette Buehler), Purdue University, for French translation assistance, proofreading and typing the manual.

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FORWARD

Sorghum is the staple food for millions of people in the Semi-Arid Tropics (SAT) regions of Africa and Asia, where the seasonal dry climate prevents the cultivation of corn and wheat. Sorghum improvement programs in the SAT must, therefore, be concerned with grain yield and the grain for human consumption. Breeders have always concentrated on improving yield, and in more recent years stability of yield. However, in the past, too little importance was placed on grain quality by breeders. This has resulted in part from the fact that it is relatively easy to objectively evaluate production performance while quality characteristics require subjective evaluation and are not easily quantifiable.

Before a new sorghum variety is released to farmers, it is important that it not only be high yielding but also have acceptable food quality. Thus, it may be necessary to sacrifice some yield in order to achieve the required food quality; everyone knows of the situation in which the improved higher yielding variety is grown for sale and the traditional lower yielding type retained for food. There is a trade off; this can only be balanced up by those involved in the production and consumption of sorghum.

In the past sorghum breeders evaluated grain quality by looking at plant color, grain color, absence of a testa, and proportion of corneous endosperm. While selecting on these criteria will sort out a great deal of unacceptable material, more exact laboratory testing procedures must be used to evalute food quality. Through recent collaborative efforts among scientists around the world a considerable amount of information has been accumulated on sorghum food quality. For example, traditional sorghum foods have been classified into nine major categories.

With the classification scheme in place, progress has been made in identifying critical grain quality factors associated with food acceptability. This has resulted in the development of many simple laboratory testing procedures for screening breeders' samples for food quality. Thus, the purpose of this Food Quality Testing Manual is to provide a comprehensive edition of the most useful methods for evaluating the inherited qualitative properties of sorghum that contribute to milling and food quality. Included in the manual are both physical and chemical methods for examining grain quality as well as micro and full scale testing procedures for screening the milling and food making properties of sorghum. Although the food quality section of the manual has been specifically developed for West Africa, other sections of the manual will be useful to any Quality Laboratory working on sorghum. As the methods in this manual have been used by Sorghum Quality Laboratories in Niger and Mali the manual will also be helpful for establishing a quality evaluation program in developing country sorghum improvement programs.

Mention of firm names or trade products in this manual does not constitute endorsement by Purdue University over others of a similar nature not mentioned.

Allen W. Kirleis
Professor of Food Science
Purdue University
W. Lafayette, IN 47907

TRADITIONAL FOOD PREPARATIONS OF SAHELIAN WEST AFRICA

To develop a program for sorghum grain quality evaluations in any region, one must first determine what sorghum food products are prepared in the region and what the desirable characteristics of those foods are. After this initial process is completed, evaluation of grain as it relates to food quality can be done. In general, sorghum food products have been divided into the following eight categories:

1. Flat Breads
2. Fermented Flat Breads
3. Thick porridge
4. Thin porridge
5. Steam cooked products
6. Boiled sorghum
7. Snack foods
8. Alcoholic and non-alcoholic beverages

Similarities have been found in traditional food preparations over ecological zones and the food products are often those which have favorable organoleptic properties when prepared with the grain types which are best grown and stored under local conditions. Although some food preparations must be prepared from a particular grain type in order to produce an acceptable food product, there are some foods which can be produced from virtually all types of grain. This report is not an attempt to define those grain types which produce favorable food quality characteristics in certain food products, but rather a description of those foods prepared from sorghum in the Niger and Mali regions of West Africa.

FLOUR PREPARATION

In all of the following food preparations with the exception of koko, decorticated sifted sorghum flour is used. This flour can be prepared manually or mechanically.

Manual Preparation

In this case, whole grain is obtained and cleaned to remove foreign matter (sticks, stones, etc.). It is transferred to a wooden mortar (approx. 3/4 meter) and water is added (approximately 300-600 ml for a 2 kg grain lot). the grain is then pounded with a pestle until it is completely decorticated. The process takes approximately 15 minutes. To separate the grain from the bran, the grain is placed in a large bowl and poured little by little to a second receiving bowl allowing the wind to blow off the bran. This process is called winnowing. The winnowed grain is placed in a bowl and covered with water for rinsing. This water is poured off and the process is repeated 3-4 times. After the last rinsing, the grain is allowed to stand in a small amount of water for approximately 15 to 30 minutes. The grain is returned to the mortar and pounded until a moist flour is obtained. The flour is sifted through a 1 mm or finer screen and the material remaining over the screen or "coarse flour" is returned to the mortar for repounding.

Mechanical Preparation

This method has become increasingly popular due to the small amount of labor involved. The whole grain is moistened and placed in a "Engleberg type" dehulling mill equipped with a screen to separate the grain and the bran. The grain and bran portions are collected by the preparer and hand sifted to separate the small grain particles from the bran portion, and the bran from the grain portion. The grain portion is rinsed with water 3-4 times and then allowed to stand in a small amount of water for approximately 15 to 30 minutes. The soaked grain is immediately passed through a flour mill. The machine consists of two metal plates (one stationary and one turning) rubbing against each other in order to break up the grain. The flour is sifted through a 1 mm or finer screen. The larger particles may be passed through the machine again.

NIGER

GALETTE-MASA-WAYNA

This food is an unleavened, fermented bread which is similar to a thick pancake. It is made from rice, millet, corn or sorghum flour, or a combination of these flours with corn being the least used of the four grains. To prepare the bread, the whole grain is decorticated and divided into 2 equal portions. The first portion is partially ground until the grains are broken into small pieces. The second half is ground into flour. The broken grain is cooked in boiling water until all water is absorbed and then vigorously mixed with a large wooden paddle to a paste. The paste is left to cool. After cooling, the flour portion is added with a small amount of salt and cayenne. The stiff paste is left in a covered pot to ferment overnight. Immediately before cooking, the paste is diluted to a cake batter consistancy and saltpeter, finely chopped onions and the leaves from the Ceratotheca sesamoides plant (yodo) are added. A small amount of wheat flour is sometimes added to increase elasticity. This batter is cooked on an iron griddle of small sunken bowls (approx. 10 cm). A generous amount of oils is added to each sunken bowl and allowed to heat before the batter is added. The batter is poured into each sunken bowl and cook on one side while hot oil is dribbled onto the uncooked side. After the first side is cooked, the masa is flipped and cooking is continued until the remaining side is brown.

GALETTE-SALA

Sala is very similar to masa, but much more greasy. It is also made from rice, millet, corn or sorghum flour which is prepared to a paste and allowed to ferment overnight. The ingredients are the same as masa, but the batter consistancy and cooking procedure are different in the following ways. After fermentation, the paste is diluted to a thicker consistancy more similar to a thin bread dough than the masa batter. This dough is shaped into small balls or large oval shapes and deep-fried in a large "wok" of vegetable oil. They are cooked on both sides to allow even browning and then drained.

BOULE-FURA-DONU

Fura is a flour, milk, and water beverage made with boiled millet or sorghum flour. Approximately 400 gm of dry flour are placed in a mortar with 60 ml of water. The flour is pounded until it is moist enough to be formed into 2-4 cm

diameter balls. These flour balls are placed in boiling water and cooked for approximately 15 minutes. Upon removal, the warm balls are returned to the mortar and repounded with the addition of a small amount of water. The cooked flour is again formed into balls and cooled. They may sit for two to several days during which time they dry out and ferment. These balls are crumbled into a variety of mixture containing combinations of the following ingredients: Milk, water, fermented milk, sugar, ginger, cayenne or roasted and ground seeds from the Acacia albida (gao) and Pterocarpus erinaceous (madobihia) trees.

BOUILLIE-KUNU-BITA

Kunu is a thin, cooked gruel which is made with millet or sorghum, and can be prepared in two ways.

The quicker preparation involves making a slurry in a large bowl using approximately 500 gm of flour and 300 ml of water. The coarseness of the flour may vary depending on the desired kunu consistancy. Two or more liters of boiling water are poured into this slurry with stirring. The solution immediately gelatinizes.

In a second type of preparation fermented flour balls as described in the fura preparation are used in place of flour. The balls are pounded to a powder and mixed with water to make a slurry as in the quick preparation method. Boiling water is poured into the slurry with stirring. This preparation produces a thin gruel with a slightly fermented flavor.

Either of these food products may be eaten warm, cold or fermented after overnight holding. Combinations of the following ingredients may also be added to the finished product: fermented milk, sugar, ginger, cayenne or the roasted and pounded seeds of the Acacia albida (gao) and Pterocarpus erinaceous (madobihia) trees.

BOUILLIE-KOKO

Koko is a gravy-like fermented beverage that is made from millet or sorghum grain and is frequently consumed warm. It is not as popular as kunu in the Niger region which may be due to the longer preparation process. In all the previous preparations the grain has been decorticated prior to flour preparation, with koko this is not necessary. The whole grain is soaked for 3-4 hours before grinding. After whole grain flour is obtained, equal portions of flour and water are mixed together in a bowl This slurry is passed through a nylon mesh into a receiving pot. The flour and bran on the nylon is then rinsed again with another portion of water before removal. The solution is covered and set overnight. After sitting, a layer of fine flour collects on the bottom of the bowl and a distinct fermented odor can be detected. The water layer is poured off and replaced with an equal quantity of boiling water. The solution will immediately gelatinize. This beverage is seasoned to taste with sugar, ginger, cayenne or the roasted and pounded seeds of the Acacia albida (gao) and Pterocarpus erinaceous (madobihia) trees.

COUSCOUS-BURABUSCO-GOUNI

Couscous is a popular dish eaten with sauce. It is a steamed grain dish consisting of small agglomerated pieces of flour. There are two types of

couscous in Niger. Each is prepared differently and each produces a slightly different food product.

The first type of couscous is more frequently prepared with rice, but sorghum and millet are also used. The whole grain is decorticated, and the dehulled grain is mechanically broken into smaller pieces. This process is not done manually as it is too difficult to obtain a consistant grain piece size with pounding in a mortar. This type of couscous can also be prepared from the material over the screen or "coarse flour" which remains after a flour preparation. This broken grain is poured into a pot with perforations in the bottom and placed on top of a pot of boiling water. The space around the outside of the two pots is filled with a bran and water paste to form a seal and to force the steam to pass through the couscous during cooking. The couscous is then allowed to steam for 30 minutes before eating.

The second preparation procedure produces a couscous which is much softer in texture. Corn, millet, sorghum, wheat or a combination of two may be used to prepare this dish. The flour is resifted to separate out the finest flour. The fine flour is set aside and water is added to the coarser flour. Water is mixed into the coarser flour by hand to completely moisten it. The finer flour is then added, again mixed by hand and then placed in a mortar. The moist flour is pounded and additional water is added. When flour is moist enough that large agglomerated particles of flour are formed, it is transferred to a bowl. The wet flour is mixed by moving the hand in a circular motion over the surface of the mixture in order to form tiny balls (1 mm). These flour balls are placed in a pot with perforations in the bottom and steamed in the previously mentioned manner for 30 minutes. The couscous is removed from the pot, moistened, broken up with a spoon and returned to the pot to cook for another 30 minutes. The couscous is again removed. Oil and salt water are added to help separate the flour balls and for seasoning. The couscous is returned to the pot and steamed for an additional 20 minutes.

PATE-TUWO -KURBA-KURBA

This is by far the most often prepared and popular sorghum dish in Niger. It is prepared from rice, millet, sorghum or wheat, and eaten with an sauce. To prepare, 2 liters of water are boiled in a large pot. The decorticated sorghum flour is resifted to separate out the finest flour. This finer flour is used to prepare a slurry of 500 gm moist flour/300 ml water. The slurry is rapidly poured into the boiling water and stirred. The flour solution will immediately thicken to a thin gel (gravy-like consistency). A small amount of water can be added to thin the consistancy. The thin gel is stirred and then covered to simmer for a few minutes. Approximately 800 ml of the thin gel is removed and set to the side while the remaining flour is placed on top of the remaining thin gel in the pot. It is slightly mixed, but the majority of flour is allowed to sit on the surface. The contents are again covered and allowed to simmer for 15 minutes. After 15 minutes the flour is completely mixed into the thin gel to make a porridge and again simmered. Before removing the porridge from the fire, the thin gel which had been placed to the side earlier is added to the porridge until the correct consistancy is obtained. The porridge is then whipped briskly to add air. It is then removed from the fire and allowed to cool before serving.

MALI

GALETTE-GWOMI

Gwomi is a fermented, fried bread which can be prepared from millet, sorghum, rice, corn or a combination of any two of the grains. It is prepared with sugar as a sweetbread or without sugar to be eaten plain or with an sauce. To begin the preparation process, 1 part finely cracked grain is poured into 5 parts of boiling water and cooked until tender. The cracked grain solution is then cooled and sifted flour is added. This mixture is covered and allowed to ferment overnight. After fermentation, the consistancy of the batter can be adjusted by adding water or flour. Sugar and salt can be added to taste and if a lighter bread is desired, baking powder may also be added. The batter, of relatively thin consistancy, is cooked on an iron griddle of small sunken bowls similar to that used in Niger for masa. A generous amount of oil is added to each bowl and allowed to heat before the batter is added. The batter is then poured into each sunken bowl and allowed to cook on one side while hot oil is dribbled onto the uncooked side. After the first side is cooked, the gwomi is flipped and cooked until the bottom side is brown.

GALETTE- FURU-FURU

The preparation of furu-furu is identical to that of gwomi with the exception of the batter consistancy and the cooking procedure. The furu-furu is cooked in a large pan of oil rather than a griddle. For this reason, the batter consistancy must be thicker than that of gwomi so that round balls can be formed in the oil and not stick to the pan. The difference in preparation procedures makes for a thicker and crispier food product. The furu-furu is allowed to brown on both sides before it is removed from the frying oil and drained.

CREME-DEGUE

There are three types of degue. The grain preparation varies among the types, but all consist of a grain/flour mixture served in cream-milk or fermented milk.

The first type of preparation is similar to the fura preparation in Niger. Decorticated grain is washed and pounded in a mortar until a mixture of approximately 25% cracked grain to 75% flour is obtained. Water may be added to slightly moisten the flour and then balls of flour are formed by hand (2-4 cm). These flour balls are placed in a small amount of boiling water and cooked for 15 minutes. The balls are then either broken up in the boiling water and allowed to cool or removed, repounded in a mortar and formed into balls again. The cooked flour is broken up into a solution of cream-milk or fermented milk, sugar and local spices (cafouné, bongôgno, mouscade and salt).

The second preparation is made with intermediate size couscous balls in a milk base. Decorticated grain is ground to a fine flour and sifted. Water is added and flour balls of 2 mm are formed by hand. This couscous is placed in a pot with perforations in the bottom and steamed over a pot of boiling water for 15 minutes. The couscous is removed, broken up and sprinkled with water. It is allowed to cool during which time a ground mixture of local spices is added (cafouné, bongôgno and mouscade). The couscous mixture is served in cream-milk or fermented milk with sugar and a small amount of salt.

The third type is made with a mixture of sifted flour, a small amount of decorticated, dry roasted grain, salt, "pain de singe" which is obtained from the ground seeds of the Adansonia digitata (baobab) tree and the local spices cafouné, bongôgno and mouscade. The mixture is allowed to dry in the sun from 1-2 days. To serve, it is sprinkled into cream-milk or fermented milk with the addition of sugar.

BOUILLIE-MONI

Moni is an acidified beverage which can be prepared from millet, sorghum, rice or corn. A fine flour is obtained from decorticated grain and water is added to moisten the flour. Flour balls (3 mm) are formed with the fingers and placed in boiling water to cook. After 5 minutes, lemon juice, tamarind juice or vinegar is added to the boiling solution and cooking continues until the flour balls are tender and a gravy-like consistancy is obtained. The cooled moni may be consumed plain or with milk and sugar.

BOUILLIE-SERI

This cooked beverage can also be prepared from millet, sorghum, rice or corn. Approximately 1 part of dehulled, whole or cracked grain is cooked in 5 parts of boiling water. Grain particle size will vary according to the preference of the preparer. The grain is boiled until tender (30 minutes) and then slightly cooled. It may be eaten warm or cold but is usually consumed the same day it is prepared. The seri may be served with milk and sugar.

BOUILLIE-BITA-RUWI

Bita and ruwi are thin, cooked gruels made from millet or sorghum with almost identical preparations. While bita may be prepared from a mixture of cracked grain and flour, ruwi is only prepared from fine flour making for a smoother gruel.

The grain is decorticated and manually pounded to obtain a mixture of fine flour and grain fragments for bita preparation or a fine flour in the case of ruwi. A slurry is prepared with approximately 500 gm of prepared grain and 300 ml of warm water. The slurry is poured into 2 or more liters of boiling water and stirred. The solution immediately gelatinizes and is briefly cooked until the grain fragments are tender. Either gruel can be eaten plain or with a mixture of milk and sugar. These gruels are the preferred food of young children, pregnant women, sick people and old people in Mali and are consumed immediately after preparation.

COUSCOUS-FOYO-BASI

There are two types of couscous in Mali, foyo and basi. Both preparations are extremely similar to those of Niger with only minor preparation differences. Foyo is prepared with dehulled, cracked grain. The grain is usually mechanically ground to obtain a consistantly fine particle size. These grain fragments are placed in a pot with perforations in the bottom and steamed over a pot of boiling water. The juncture between the two pots is sealed with a damp cloth to force the steam through the perforations and grain. The wet cloth is wiped with okra (Abelmoscus esculentus) powder to assure a tight seal. In the absence of a cloth, a mixture of mud and okra powder is used to seal the

two pots. The couscous is steamed 3-4 times for 30 minutes each. Between each steaming, the couscous is mixed and water is added. Before the final steaming, dry okra powder may be added. The grain fragments may also be cooked in boiling water with peanut flour to prepare a dish called laro.

To prepare basi, whole or dehulled grain is reduced to flour, which is sifted through a sieve with 1 mm mesh openings. Only the flour that passes through that sieve is used for the preparation. The flour is wetted with cool water and agglomerated into small balls by hand. The agglomerated flour particles are sifted through a 1.5 mm opening screen. The wet aggregates (1 mm) are placed in a covered perforated pot and steamed. After about 15 minutes of steaming, the agglomerated flour particles form a large single chunk, which is taken out of the bowl, broken up and again steamed for an additional 15 minutes. The particles are again broken up into single units and sifted through a 2.5 mm sieve. At that point, the steamed couscous is sprinkled with cool water and mixed thoroughly. Baobab (Adansonia digitata) leaf powder is mixed with the particles. This powder serves as a lubricant, which prevents dessication and stickiness, and improves palatability. Okra powder can be used as a substitute for baobab leaf powder. After mixing, the aggregates are again placed in the perforated bowl and steamed for about 15 minutes. The couscous is allowed to cool slowly and is served with sauce.

ALKALI PATE-Tô

This Malian dish is prepared from a variety of grains and is normally eaten with an sauce. To prepare, four liters of water are brought to a boil in a metal pot over a fire. The flour is passed through a sieve with 1 mm mesh openings. Approximately 650 ml of cool water are mixed with 10 g of wood ash extract and about 750 g (500 g dry wt.) of sorghum flour in a calabash or bowl. The mixture is stirred until homogeneous and then swirled into the boiling water in the pot. The boiling slurry is stirred for about 8 minutes until it thickens. At this point, a portion of the thin gel is removed from the pot and set aside in a calabash. About 1,125 grams (750 g dry wt.) of sorghum flour is added, a handful at a time, to the thin gel in the pot. After each addition of the flour, the paste is vigorously whipped with a flat wooden paddle. When the paste thickens too much for easy whipping, a small amount of thin gel from the calabash is added. The addition of flour with the addition of thin gel continues until the porridge is finished and the paste is homogeneous and very thick. This step takes about 9 minutes. All large pieces of wood are removed from the fire and only small embers are allowed to remain. The thickened porridge is covered and allowed to cook over the low heat for about 12 minutes. The tô is removed from the fire, uncovered and scooped into serving bowls where it is allowed to cool and set for at least one hour before serving.

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III. LABORATORY METHODS

A. PHYSICAL ANALYSIS

ESTIMATION OF STOCK COMMODITY GRAIN PURITY

Apparatus

- Sifting screens of various meshes (1 mm, 2 mm, 3 mm, 4 mm, 5 mm)
- Bottom pan
- Grain sample splitter
- Chondrometer (Corcoran-Simplex Limited)
- Balance
- Moisture meter or drying oven (103°C)

Procedure

Sample Cleaning

1) Put sifting screens in place (largest screen opening on top, smallest openings on bottom) and put representative sample onto screens. Normal sample size is 1-2 kg.
2) Close top screen with lid and vigorously shake for a few minutes. Remove cover.
3) Material remaining in screens are grain and foreign substances. Debris is material found in the bottom pan (immature grain, dust etc.) Put debris in a container and resift.
4) Collect grain found in different screens.
5) By hand, sort out foreign substances (other grain, stones etc.). Put these in a separate container.
6) When this operation is completed, weigh the following fractions and record weights of grain, foreign substances and debris on data sheet.
7) Prepare 3, labeled, plastic sacks and place each fraction in a sack.

Grain Fraction Analysis

1) Determination of Percent Moisture

   Take 10 g of grain. Grind in a blender. Determine moisture content by the Determination of Moisture Method CA-2. Record result on data sheet.

2) Weight per Unit Volume Determination (kilograms/hectoliter)

   This measurement is made with a chondrometer (see method PA-3). Record measurement on data sheet.

3) Determination of the Ratio of Whole Grain to Attacked Grain

   Prepare a representative subsample of about 25 g from original grain sample. By hand, separate whole undamaged grain from attacked grain (grain which is insect infected, molded, or broken). Record weight of attacked grain and whole grain on data sheet.

Calculations

Calculate the percent grain, foreign substances and debris of the original sample.

$$\% \text{ Grain} = \frac{\text{wt. of grain} \times 100}{\text{original sample wt.}}$$

$$\% \text{ Foreign Substances} = \frac{\text{wt. of foreign substances} \times 100}{\text{original sample wt.}}$$

$$\% \text{ Debris} = \frac{\text{wt. of debris} \times 100}{\text{original sample wt}}$$

Calculate the ratio of whole grain to attacked grain.

$$\% \text{ Whole Grain} = \frac{\text{wt. of whole grain} \times 100}{\text{wt. of whole grain and attacked grain}}$$

$$\% \text{ Attacked Grain} = \frac{\text{wt. of attacked grain} \times 100}{\text{wt. of whole grain and attacked grain}}$$

DATA SHEET FOR ESTIMATION OF STOCK COMMODITY GRAIN PURITY

Name: _____

I. GENERAL INFORMATION

Sample No.
Location
Date of arrival
Variety

II. SAMPLE WEIGHT ON ARRIVAL

	wt.	%
Grain		
Debris		
Foreign substances		
Total sample wt.		

III. GRAIN ANALYSIS

Moisture
kilos/hectolitre

	wt.	%
Whole grains		
Attacked grains		
TOTAL:		

IV. COMMENTS:

FIGURE 1

PREPARATION OF A REPRESENTATIVE WORKING SAMPLE USING A GRAIN DIVIDER

Definition

This method provides a means of obtaining a representative working sample from a large laboratory grain sample by means of a sample divider.

Apparatus

Grain divider or equivalent

Procedure

1) Place two square sample cups side by side and attach divider to the two sample cups.

2) Fill third sample cup with grain and level off.

3) Line up the edge of the sample cup with divider and slowly empty sample into divider.

   This procedure results in two subsamples of equal weights. To obtain smaller samples this procedure is repeated using the subsample from the previous division. Subsamples of 1/4, 1/8, 1/16, 1/32 etc. can be obtained by successive divisions.

PREPARATION OF A REPRESENTATIVE WORKING SAMPLE BY QUARTERING

Definition

This method provides a means of obtaining a representative working sample from a large laboratory grain sample by means of "quartering". The quartering technique should be used in cases where a grain divider is not available.

Apparatus

- Flat surface
- Ruler or straight edge

Procedure

1) Place original grain sample on a flat surface and spread grain into a circle.
2) With a ruler or by hand, divide sample into quarters.
3) Remove 3 quarters and replace in sample bag.
4) Remaining quarter is again shaped into a circle and quartered. This process is repeated until desired amount of sample is obtained (see figure below).

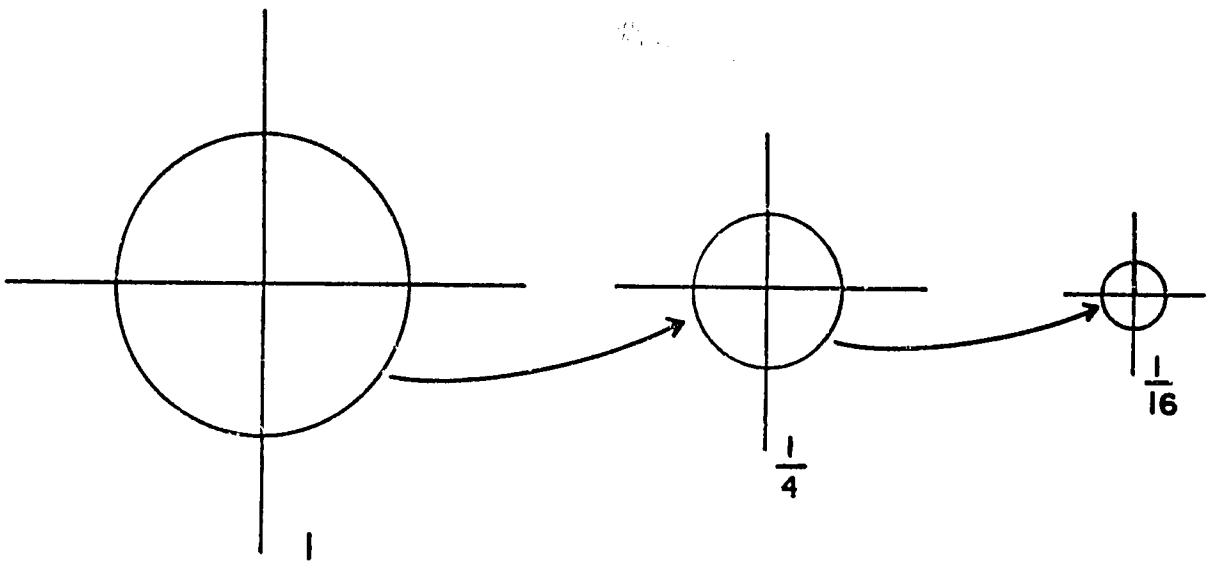


FIGURE 2

DETERMINATION OF GRAIN WEIGHT PER UNIT VOLUME

Apparatus

Chrondrometer apparatus (Corcoran-Simplex Limited*) or equivalent

Procedure

Chondrometer Instructions

(1) Insert cut-off knife (A) in top of weighing bucket. (B)

(2) Fit filling tube (D) above weighing bucket with the plunger (C) resting on the face of the knife.

(3) Load filling tube with cleaned grain to within approximately 1/2" of the top.

(4) Withdraw knife. As soon as knife allows the plunger to fall, the plunger and the column of grain above it will fall into the weighing bucket, air being pushed out through the holes in the bottom (which must be kept clear) and thus giving a constant filling.

(5) Re-insert cut-off knife, pushing home fully.

(6) Without removing filling tube, empty out surplus grain.

(7) Remove filling tube and knife.

(8) Place the full weighing bucket on weighing platform and balance out with sliding weight on the beam, reading off weight in "lbs. per bushel" or "kilos per hectolitre" as required.

* Sterling Industrial Estate
Rainham South Road,
Dagenham, Essex RM 108DJ
United Kingdom

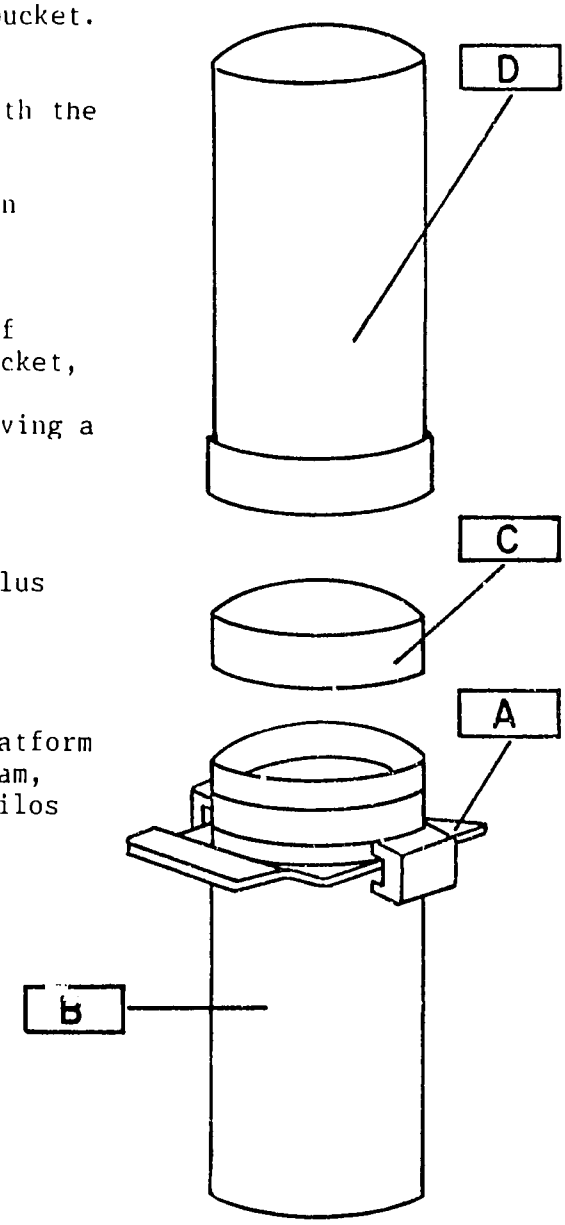


FIGURE 3

ANALYSIS OF PHYSICAL CHARACTERISTICS OF SORGHUM GRAIN

Apparatus

- Sheet of white paper
- Razor blade
- Balance
- Graduated cylinder (100 ml)
- Ethanol
- Data sheet

Procedure

Physical characteristics analyzed include grain color, pericarp thickness, presence or absence of testa, endosperm color, endosperm texture, 100 kernel weight, and grain density. All of these analyses should be done on representative grain samples and results of these analyses as well as No. I.D. (variety identification number) and No. I.S. (international sorghum number) should be recorded on data sheet.

Grain Color

1) Place a few kernels of sample on a piece of white paper.
2) Observe color of pericarp (outside coat of grain) and rate according to the following scale. Record on data sheet.

   1 - white
   2 - yellow
   3 - red
   4 - maroon, brown
   1/3 - bicolored (ex. white and red grain)

Note that if pericarp is transparent, observed color can be affected by endosperm. Consequently, pericarp thickness affects observed color.

Pericarp Thickness

1) Scrape kernel with razor to remove pericarp.
2) Observe thickness of pericarp. A thin pericarp usually scrapes off in small fragments while a thick pericarp will come off in thin sheets.
3) Use the following numerical scale to rate pericarp thickness. Record on data sheet.

   1 = thin pericarp
   2 = medium pericarp
   3 = thick pericarp

Testa

In some sorghum varieties, a heavily pigmented layer called testa, is found just under the pericarp. This purple and brown testa layer is thickest at the crown of the kernel and thinnest around the embryo or germ. To judge presence or absence of testa scrape kernel to remove pericarp or crown. The presence of a pigmented layer covering endosperm indicates presence of testa. Record on data sheet:

+ = testa present
- = testa absent

Endosperm Color and Texture

Endosperm is composed of a vitreous part and a floury part. To observe the two parts, cut kernel longitudinally into two symmetrical halves. Observe and rate color of the vitreous endosperm according to the following scale.

a. white
b. yellow
c. gray
d. red

Relative proportion between vitreous region and floury region is reference for determining endosperm texture. Again observe longitudinal cut of kernel and rate endosperm texture according to the following scale:

1 - 100-80% vitrosity (vitreous texture)
2 - 80-60%
3 - 60-40%
4 - 40-20%
5 - 20-0% (floury texture)

This method for evaluating endosperm texture should not be confused with the "Bono method" which rates grain vitrosity from 0 to 4 with 4 as most vitreous.

100 Kernel Weight

Weigh out 40 g of grain. Count number of kernels. 100 kernel weight is calculated by the following formula:

$$\frac{40 \text{ g} \times 100}{\text{number of kernels in 40 g}} = 100 \text{ kernel weight}$$

For samples less than 40 g two additional methods may be used to determine 100 kernel weight

1) Count 100 kernels. Weigh on balance and record weight on data sheet.
2) Count 300 kernels. Weigh on balance and divide weight by 3. Record weight on data sheet.

Grain Density

1) Pour 96% ethanol into a 100 ml graduated cylinder. Note exact volume (Vo).
2) Weigh 20 g of grain.
3) Pour grain into graduated cylinder + ethanol. Note new volume (V).
4) Calculate grain density and record on data sheet.

$$\text{grain density (g/ml)} = \frac{\text{grain weight}}{(V - Vo)}$$

References

Rooney, L.W. and F.R. Miller. 1981. Variation in the structure and kernel characteristics of sorghum. p 143-162. In International Symposium on Sorghum Grain Quality. ICRISAT Center, Patancheru, India, 28-31 Oct 1981.

House, L.R. 1980. A Guide to Sorghum Breeding. p 205. ICRISAT, Patancheru, India.

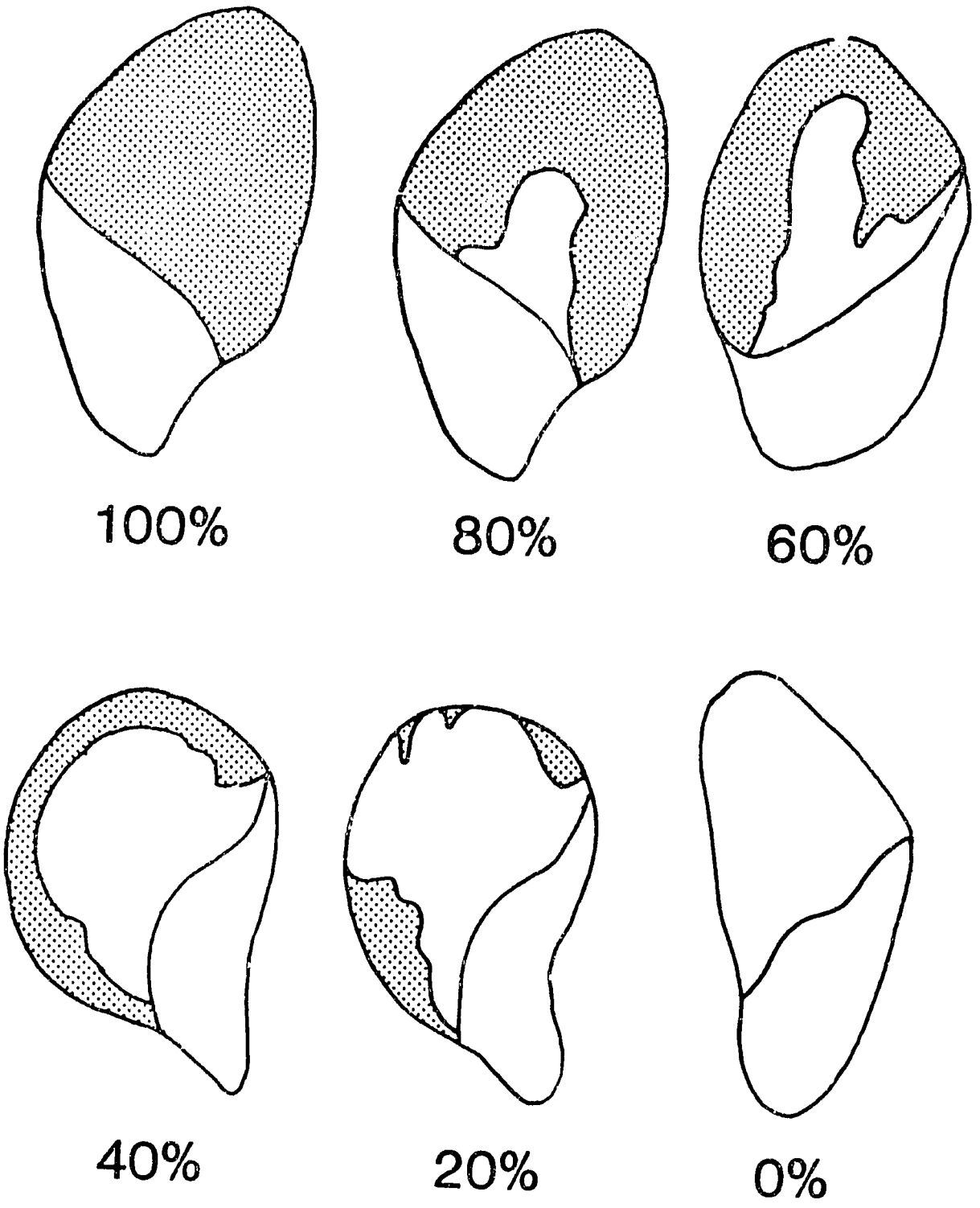
PA-4

DATE_____ LAB TECHNICIAN_____

PHYSICAL CHARACTERISTICS ANALYSIS OF SORGHUM GRAIN

NO. ID.	NO. IS	VARIETY	COLOR OF GRAIN	THICKNESS OF PERICARP	TESTA	COLOR OF ENDOSPERM	TEXTURE OF ENDOSPERM	WT. OF 100 GRAINS	NUMBER OF GRAINS IN 40 G	DENISTY OF GRAIN

FIGURE 4



ENDOSPERM TEXTURE

FIGURE 5

ANALYSIS OF PHYSICAL CHARACTERISTICS OF SORGHUM PANICLE

Apparatus

Data sheet
Ruler

Procedure

Panicle characteristics analyzed include panicle shape, panicle length, panicle width, glume color, and glume length (percent grain covered by glume). These analyses should be done on an average grain head, representative of the variety. Results of these analyses, as well as No. I.D. (variety identification number) and No. I.S. (international sorghum number), should be recorded on data sheet.

Panicle Shape

Compare sorghum grain head to those on attached reference table (p 21). Record panicule reference number that corresponds to sample.

Ex: 1 corresponds to open head.

Panicle Length (cm)

Place panicle on a flat surface. With a 40 cm ruler measure length of head which starts at first branches and ends at tip of head. Record length on data sheet.

Panicle Width (cm)

Place panicle on a flat surface and measure at center of the head. Do not push down on head because it will increase width. Record width on data sheet.

Glume Color

Observe glumes and rate color according to the following code: Record on data sheet.

1 - pale, tan
2 - red
3 - purple
4 - black

Glume Length or Percent Grain Covered by Glume

Using reference table (p. 21), rate glume length according to the following code: Record on data sheet.

1 - Fully covered grain
2 - 75% of grain covered
3 - 50% of grain covered
4 - 25% of grain covered
5 - Uncovered grain

Reference

House, L.R. 1980. A Guide to Sorghum Breeding. p 204. ICRISAT, Patancheru, India.

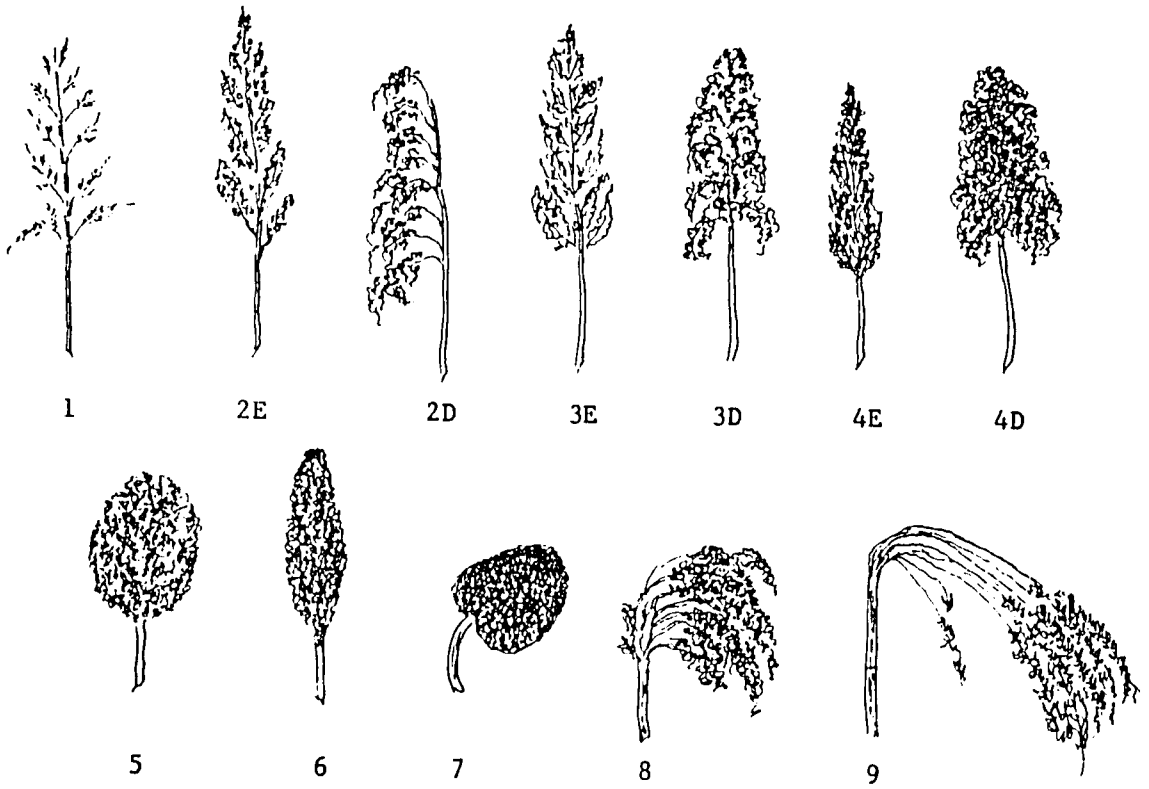
PA-5

DATE_____ LAB TECHNICIAN_____

PHYSICAL CHARACTERISTIC ANALYSIS OF THE SORGHUM PANICLE

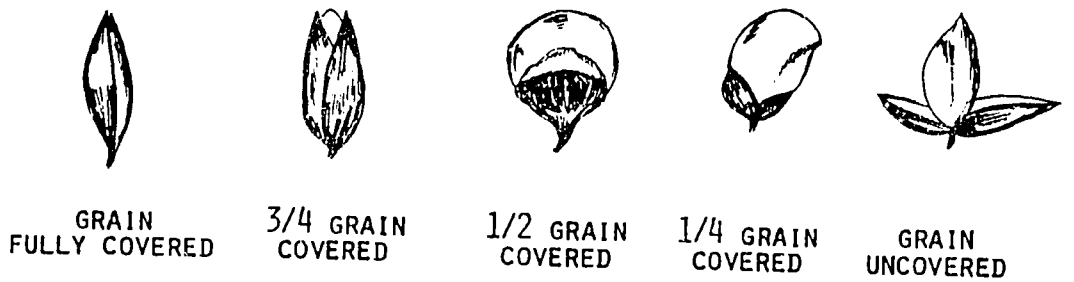
NO. ID.	NO. IS	VARIETY	FORM OF PANICLE	LENGTH OF PANICLE	WIDTH OF PANICLE	COLOR OF GLUMES	LENGTH OF GLUMES	REMARKS

FIGURE 6



PANICLE SHAPE

FIGURE 7



GLUME COVERING

FIGURE 8

DETERMINATION OF GRAIN HARDNESS-PERCENT FLOATERS METHOD

Percent floaters method has been developed for use in determining hardness of grain. This information is useful as cultivars with vitreous or hard endosperm have been found to yield better grain recovery after dehulling than those with floury or soft endosperm. Grain hardness is measured as percent of floating kernels in a $NaNO_3$ solution. Specific gravity of the $NaNO_3$ solution must be selected in order to provide good separation of those varieties being tested.

Apparatus

- Magnetic Stir Plate
- Stir bar
- Beaker (2 liters)
- Hydrometer (1.000 - 2.000 specific gravity)
- Filter paper
- Apparatus I: plastic funnel (top i.d. 150 mm, stem length 30 mm, stem (see diagram) o.d.28m)
- Beaker (2 liters)
- Wire rod (28 cm)
- Fine screen (5 cm diameter)
- Coarse screen (5 mm opening)

Reagents

- $NaNO_3$ (technical grade sodium nitrate)
- Triton X-100 (alkylaryl polyether alcohol, Trademark of Rohm and Haas Co.) or a water soluble organic solvent to break the surface tension.

Procedure

1) Dissolve approximately 805 g of $NaNO_3$ in 2 liters of distilled water on a magnetic stir plate. Add 3 drops of triton.
2) Use hydrometer to determine the specific gravity of solution.
3) Adjust specific gravity to 1.205 by addition of water if the value is too high or with $NaNO_3$ if the value is too low.
4) Prepare 3 subsamples of 100 kernels each for each variety to be tested. Moisture content among grain samples should be within 1%.
5) Fill the 2 liters beaker 3/4 full with the $NaNO_3$ solution. Add funnel and rod.
6) Introduce 100 kernel sample into funnel.
7) Stir solution with rod for 30 seconds.
8) Leave kernels to separate in solution.
9) Collect floating kernels by closing funnel opening with the rod screen and lift them out.
10) Place these on a filter paper for counting.
11) Their number is equal to percentage of floating kernels.
12) Remove kernels that remain in the beaker.
13) Do 3 determinations for each sample being tested.

Calculation

Percent floaters is obtained by taking the average of the 3 determinations

$$\text{Percent Floaters} = \frac{\text{Determination 1} + \text{Determination 2} + \text{Determination 3}}{3}$$

Modification

If the materials for apparatus I are not available, apparatus II can be used.

1) Place a flour screen (19 cm x 8 cm) in a glass bowl with a flat bottom (21 cm x 11 cm) containing 2 liters of $NaNO_3$ solution.
2) Add 100 grain sample and stir solution with a stirring rod for 30 seconds.
3) Remove floating kernels with a tea strainer and count kernels to make percent floaters calculation.
4) Remove flour screen from solution and remove remaining kernels.
5) Replace flour screen into solution for the next determination.

References

Kirleis, A.W. and K.D. Crosby. 1981. Sorghum Hardness: Comparison of methods for its evaluation. p 231-241. In International Symposium on Sorghum Grain Quality. ICRISAT Center, Pantancheru, India, 28-31 October 1981.

Wicher, W.R. 1961. The world of corn processing. American Miller Processor. 89(3):23-24; 89(4):29-31.

ICRISAT/Mali Annual Report, 1985.

Hallgren, L. and D.S. Murty. 1983. A screening test for grain hardness in sorghum employing density grading in sodium nitrate solution. J. Cereal Science 1:265-274.

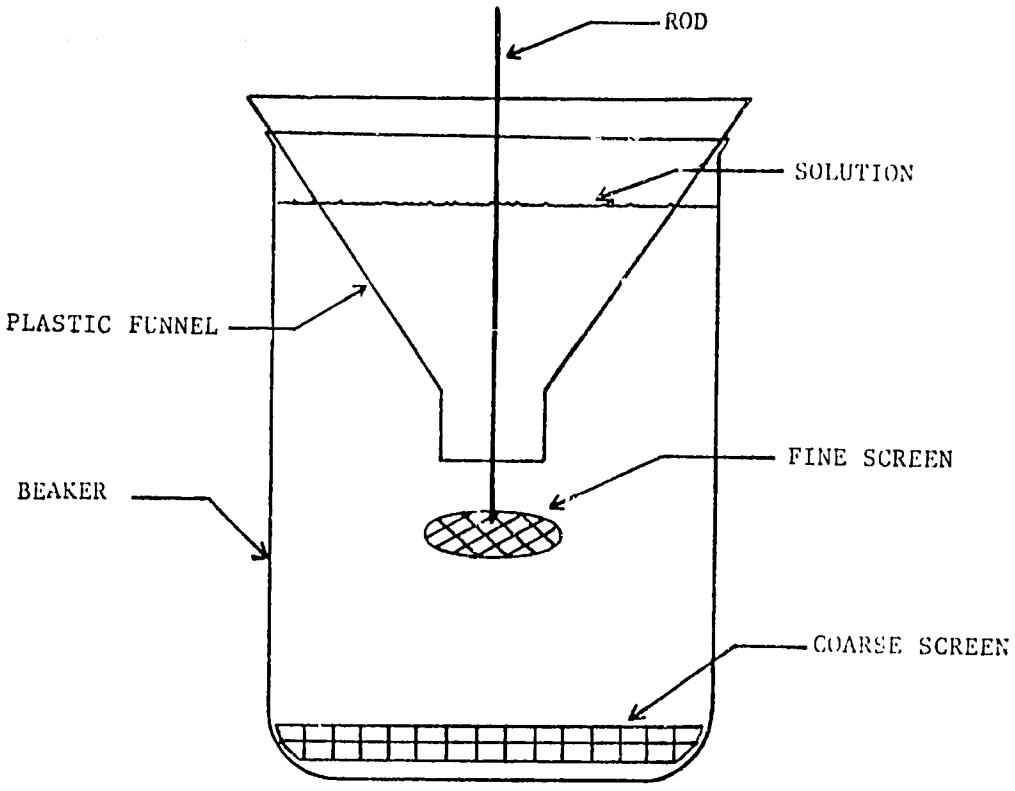
DATE_____ LAB TECHNICIAN_____

DETERMINATION OF GRAIN HARDNESS

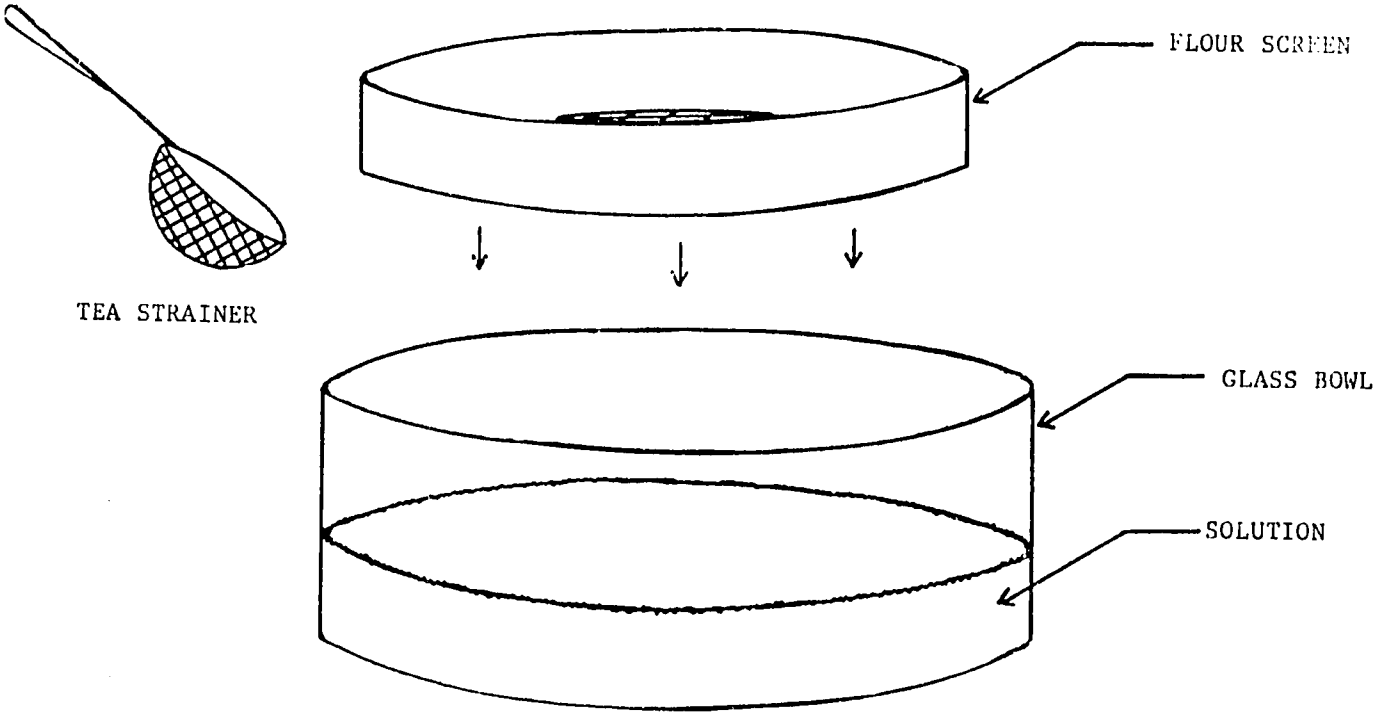
SPECIFIC GRAVITY_____

SAMPLE	DETERMINATION 1	DETERMINATION 2	DETERMINATION 3	AVERAGE PERCENT FLOATERS
1				
2				
3				
4				
5				
6				
7				
8				
9				

FIGURE 8



APPARATUS I



APPARATUS II

FIGURE 10

III. LABORATORY METHODS

B. CHEMICAL ANALYSIS

NITROGEN DETERMINATION

Most commonly, protein assay procedures depend on determining a specific element or group in protein. In the case of Kjeldahl method, protein-nitrogen is measured. Organic nitrogen in the sample under analysis is converted to NH_4^+ by digestion with concentrated H_2SO_4 and a catalyst. NH_4^+ is determined from amount of NH_3 liberated by distillation of digest with alkali. NH_3 liberated by distillation is collected in a volume of H_3BO_3 and determined by titration with standard H_2SO_4. This method is accurate in determining the amount of protein in foods since presence of non-protein nitrogen compounds is as a rule, small compared to protein content of most foods.

Reaction

Digestion:

$$\text{Organic N} + H_2SO_4 + \text{catalyst} \longrightarrow NH_4^+$$

Distillation:

$$NH_4^+ + NaOH \longrightarrow NH_3\ (g)$$

$$NH_3 + H_3BO_3 \longrightarrow NH_4^+ + H_2BO_3^-$$

Titration:

$$H^+ + H_2BO_3^- \longrightarrow H_3BO_3$$

Materials

- Weigh plate
- Kjeldahl flasks (100 ml)
- Spatula
- Digestion apparatus
- Distillation apparatus
- 6 Erlenmeyer flasks (125 ml)
- Graduated cylinder (50 ml)
- Boiling stones
- Buret (50 ml)
- Stir plate
- Stir bar
- Analytical balance

Reagents

- Sulfuric acid (36N, d = 1.83)

- Catalyst
  potassium sulfate - 100 g
  copper sulfate - 20 g
  selenium - 2 g

Finely grind together in a grinder or Waring blender until a homogenous powder is obtained.

- Boric Acid/Indicator solution

Dissolve 80 g of boric acid into one liter of boiling water. Let cool. Combine 25 ml of indicator and the boric acid solution in a 2 liter volumetric flask. Dilute to volume with distilled water.

- Indicator

3 parts 0.1% bromocresol green in ethanol
1 part 0.1% methyl red in ethanol

Place 0.1 g bromocresol green and 0.1 g methyl red into separate 100 ml volumetric flasks. Dilute both flasks to volume with ethanol. Mix 75 ml bromocresol green solution with 25 ml methyl red solution.

- Sodium hydroxide (10 N)

Prepare solution in a 1 liter beaker which is placed in a cold water bath. Add distilled water to 400 g of sodium hydroxide stirring constantly. Let cool. Transfer to a 1 liter volumetric flask and dilute to volume after cooling.

- Sulfuric acid (1 N)

Place 27.8 ml of concentrated sulfuric acid in a 1 liter volumetric flask. Dilute to volume with distilled water.

- Sulfuric acid (approx. 0.0500 N)

Place 50 ml of 1 N sulfuric acid into a one liter volumetric flask, and dilute to volume with distilled water.

- Octanol (optional)

Procedure

Digestion

1) In a dry, 100 ml Kjeldahl flask, introduce 0.25 g of finely ground sample and 0.5 g of catalyst. Shake flask to mix. Add 3 ml of concentrated H_2SO_4, swirl. Prepare blank under same conditions but with no sample added.

2) Heat flasks inclined on a digestion rack apparatus. Maintain a low heat for 40 minutes and then raise to medium heat for one hour. Digestion is finished when the solution has been clear for 30 minutes.

3) Cool for 30 minutes.

Distillation

1) Rinse flask neck with distilled water and quantitatively transfer digested sample into a distillation flask rinsing 3 to 4 time with distilled water.

2) Add 3 boiling stones, 3 drops of octanol and approximately 60 ml of water to each flask. Octanol will prevent foam from moving up flask.

3) Place flasks on distillation apparatus.

4) Collect ammonium (NH_3) in an Erlenmeyer flask containing 20 ml of boric acid/indicator solution. Collection tube must be immersed in solution.

5) To each distillation flask, add 15 ml of NaOH (10 N).

6) Immediately attach flasks to distillation apparatus. Swirl gently.

7) Boil sample at low heat at first and then to a medium heat until distillation is finished.

8) Continue distillation until 50 ml of solution have been collected in the boric acid/indicator solution. Indicator will turn green.

9) Lower Erlenmeyer flasks and continue distillation for 5 minutes. Rinse collection tube and remove flasks.

Note: Between 2 series of distillations, rinse distillation apparatus by distilling water.

Titration

1) Fill buret with sulfuric acid solution (approx. 0.0500 N)
2) Place a magnetic stir bar in each flask.
3) Place a flask on stir plate.
4) Titrate with 0.05 N sulfuric acid solution. At reaction end point, solution will turn from green to pink.
5) Note volume of acid used (V)
6) Titrate a blank. Note volume of acid used (V_o)

Calculations

Percent nitrogen contained in the sample is calculated by the following formula:

$$\%N = \frac{(V-V_o) \times (H_2SO_4 \text{ Normality}) \times (\text{atomic wt. of nitrogen}) \times 100}{(\text{sample wt. in grams}) \times 100}$$

$$\%N = \frac{(V-V_o) \times N \times 14.0 \times 100}{0.250 \times 1000}$$

$$\%N = (V-V_o) \times N \times 5.60$$

$$\% \text{ Protein} = 6.25 \times \%N$$

Modification

For samples that foam or are rich in organic matter, an addition of hydrogen peroxide (H_2O_2, 30%) will give a clear solution more rapidly. In such a case, proceed in the following manner:

1) After flasks have been placed on digestion apparatus, heat until the foam moves to flask neck. Remove flasks from heat and slowly add 1 ml of 30% H_2O_2 down flask neck.

2) If there is still an excess of foam, add 0.5 ml - 1.0 ml of 30% H_2O_2. Continue to heat samples for 5 minutes after solution clears.

3) Run a blank under same conditions.

Precautions

- The H_2O_2 solution (30%) must be added to the digestion flask with great care. Make the addition under a fume hood with the flask mouth aimed away from your face due to rapid evolution of gas on addition.

- Cool blank a few minutes before adding hydrogen peroxide because it can rapidly decompose at high temperatures in the absence of organic matter.

References

ASA Monograph No. 9. 1965. Methods of soil analysis. Part II.

Concon J.M. and Diane Soltess. 1973. Rapid micro-Kjeldahl digestion of cereal grains and other biological materials. Anal. Biochemic 53:35-41.

Pomeranz. Y and C. Meloan. 1978. Food Analysis: Theory and Practice (Revised Edition). p. 671. AVI Publishing Company Inc., Westport, Conn.

FACTOR TO CONVERT PERCENT N TO PERCENT PROTEIN

Cereals:	Factor
Sorghum (*Sorghum* spp.)	6.25
Millet (Pennisetum spp.) grain	6.25
Foxtail Millet (*Setaria italica*)	6.25
Proso Millet (*Panicum miliaceum*) husked	6.25
Maize (*Zea mays*) (grain or whole meal)	6.25
Rice (*Oryza* spp.) brown or husked	5.95
Wheat (*Triticum* spp.) whole grain	5.83
Wheat (Triticum spp.) germ	6.31
Wheat (Triticum spp.) bran	6.31
Wheat (Triticum spp.) flour	5.70
Wheat (Triticum spp.) parboiled (Bulgur)	5.83
Teff (*Eragrostis tef*) whole	6.25
Rye (*Secale cereals*) whole meal	5.83
Barley (*Hordeum vulgare*) whole seed	5.83
Oats (*Avena sativa*) meal	5.83
Buckwheat (*Fagopyrum sagittatum*) hulled, dark flour	6.25

INSTRUCTIONS FOR THE PREGL DISTILLATION APPARATUS IN NITROGEN DETERMINATIONS (KJELDAHL METHOD)

The distillation apparatus developed by Parnas and Wagner can be used as an alternative to the typical apparatus. Although more time consuming, this method has proved to be less harsh on glassware which may be a consideration when glassware is limited.

Materials

- Distillation apparatus (see diagram)
- Erlenmeyer flask (125 ml)
- 2 Beakers (500 ml)

Reagents

- Boric acid/Indicator solution - see Nitrogen Determination - CA-1
- Sodium hydroxide (NaOH, 10 N) - see Nitrogen Determination - CA-1

Procedure

1) Fill glass kettle (B) with distilled water.
2) Grease kettle cover and place on kettle. Secure cover with small vises.
3) Open all pinchcocks (C, D, E) and remove rubber stopper (K) from kettle.
4) Put 20 ml of boric acid/indicator solution in a 125 ml Erlenmeyer flask and place it under condenser so that receiving tube is submerged in solution.
5) Rinse digestion flask 3-4 times with distilled water into funnel (F). Fill distillation flask (G) with sample adding distilled water to a height of 5 cm.
6) Add 20 ml of NaOH to distillation flask.
7) Close pinchcocks D and E (not C), and boil water in kettle.
8) Turn on water source for condenser.
9) The sample will boil. If it does not, check connecting tubes to make sure there aren't any leaks.
10) Adjust temperature with regulator (A).
11) Continue distillation. When 50 ml of solution has been collected in the Erlenmeyer flask (I), lower flask. Remove collection tube from solution. Wait 3 minutes.
12) Turn off regulator. Rinse collection tube into flask with distilled water. Remove flask.
13) Procede to titrate the solution (see Nitrogen Determination - CA-1).

Cleaning

1) Attach a 125 ml Erlenmeyer of distilled water to condenser.
2) Close pinchcocks D and E. Open pinchcock C.
3) Treat for a few minutes. Close stopcock C, and remove kettle stopper. All the water contained in the Erlenmeyer and the traces of sample will be sucked by vacuum to steam trap (J). Open pinchcock C and empty steam trap with pinchcock D.
4) Rinse filling funnel (F) with 100 ml of distilled water and refill Erlenmeyer with water.
5) Replace kettle stopper and continue with vapor procedure. Remove kettle stopper (K). Close pinchcock C, and proceed as in step 3.
6) Repeat procedure 3 times.

References

A Steyer mark, Quantitative Organic Microanalysis, 2nd Edition, Academic Press, N.Y. (1961).

ASTM Tentative method E-147-59 T, ASTM Standards, 1959 Supplement, Part 7 (Petroleum).

Committee on Microchemical Apparatus, Divn. of Analy. Chem., ACS. See Analytical Chemistry, Vol. 23, No. 3, p. 524 (March 1951).

DISTILLATION APPARATUS (KJELDAHL METHOD)

A.S.T.M.-Pregl

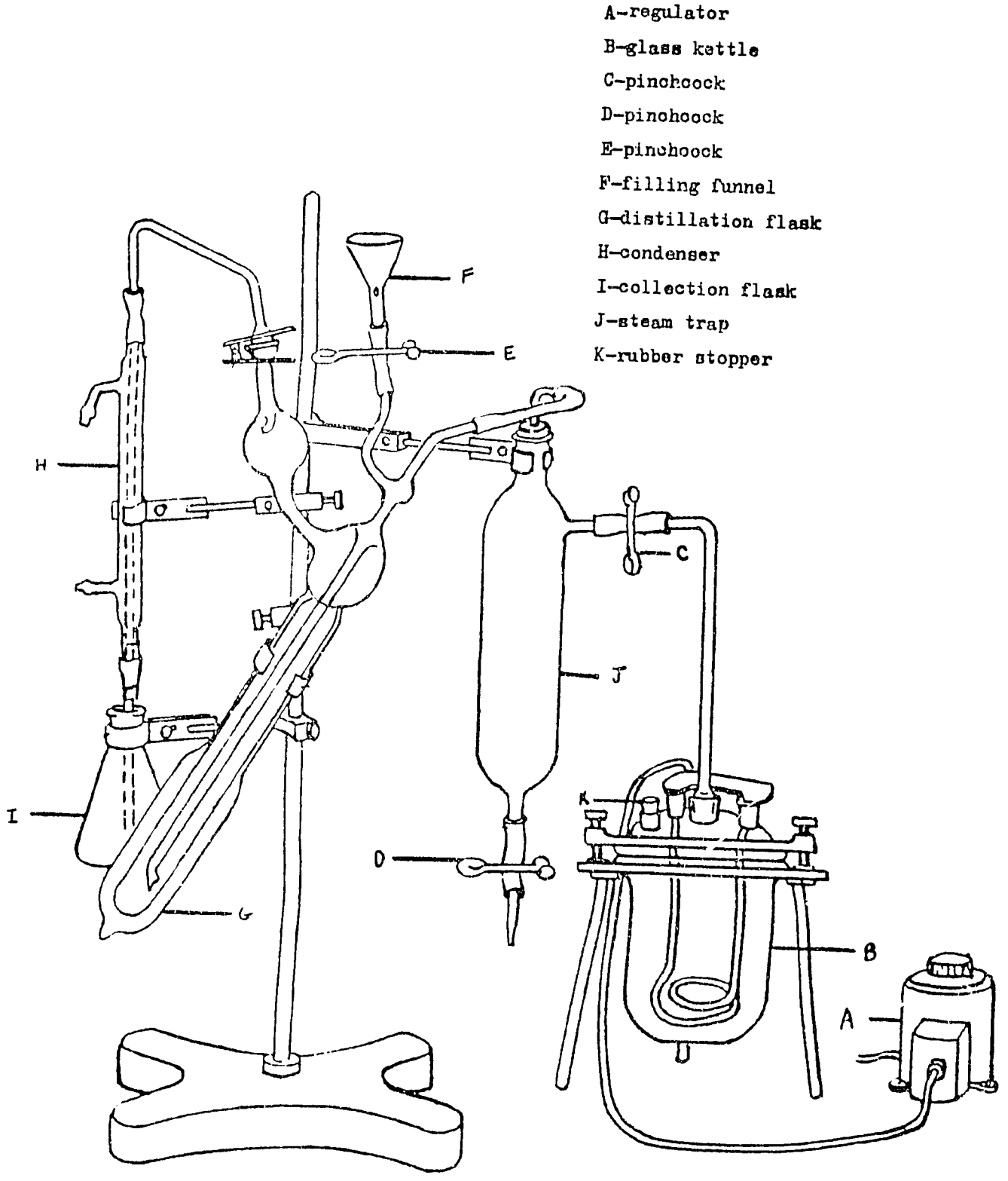


FIGURE 11

DETERMINATION OF TITRATION ACID NORMALITY

Materials

- Drying oven (95°C)
- Dessicator
- Crucible
- Volumetric flask (1000 ml)
- 3 Erlenmeyer flasks (50 ml)
- 3 Magnetic stirring bar
- Magnetic stir plate
- 10 ml buret

Reagents

- Indicator

  - Prepare: 3 parts of bromocresol (0.1% in alcohol) to 1 part of methyl red (0.2% in alcohol)

See Nitrogen Determination - CA-1

- Tris (hydroxymethyl) aminomethane (THAM) Solution - (0.01 N)

Place 2 g of THAM in a crucible. Leave in a drying oven (95°C) overnight. Let cool in a desiccator. In a one liter volumetric flask, dissolve 1.2114 g of oven dried THAM in distilled water. Complete to volume.

Procedure

Using a volumetric pipet, put 20 ml portions of THAM solution in 3 Erlenmeyer flasks (50 ml). Add 3-5 drops of indicator to each flask and swirl. Titrate each solution with the acid in question to a light pink end point color. Note the acid volume used.

Calculation

$$\text{Average acid volume} = \frac{\text{Volume 1} + \text{Volume 2} + \text{Volume 3}}{3}$$

$$\text{Acid Normality} = \frac{\text{mls. THAM} \times \text{THAM Normality}}{\text{average acid volume (A.A.V.)}} = \frac{20 \text{ ml} \times 0.01 \text{ N}}{\text{A.A.V.}}$$

STANDARD SOLUTION PREPARATION TO TEST PERCENT NITROGEN RECOVERY LEVELS AFTER DIGESTION

Materials

- Crucible
- Drying oven (95°C)

Reagents

- EDTA (MW = 372.2)

Place EDTA in a crucible and dry in a drying oven (95°C) overnight. Transfer to a desiccator and let cool.

Procedure

Place 0.100 g of dry EDTA in a Kjeldahl flask. Run sample through digestion and distillation processes under the same conditions used for the nitrogen determination procedure. See Nitrogen Determination - CA-1.

Calculation

$$\% \text{ Recovery} = \frac{(V-V_0) \times N \times 186.1 \times 100}{\text{sample weight (g)} \times 1000}$$

$$= \frac{(V-V_0) \times N \times 186.1 \times 100}{0.100 \times 1000}$$

N = Sulfuric acid normality

V = Volume of H_2SO_4 used for EDTA

V_o = Volume of H_2SO_4 used for blank

186.1 = Molecular eqivalents of EDTA = $\frac{\text{molecular weight}}{2}$

STANDARD SOLUTION PREPARATION TO TEST PERCENT RECOVERY LEVELS OF A DISTILLATION PROCESS

Materials

- Crucible
- Desiccator
- Drying oven (95°C)
- 2 volumetric flasks (1000 ml, 500 ml)
- Pipet (50 ml)

Reagents

- $(NH_4)_2SO_4$ (Ammonium sulfate)

  Place 6 - 7 g of ammonium sulfate in a crucible and dry in a drying oven (95°C) overnight. Transfer to desiccator and let cool.

- Ammonium sulfate solution (0.12 mg/ml)

  In a 1 liter volumetric flask, dissolve 5.663 g of dry ammonium sulfate in distilled water. Dilute to volume with distilled water.

Procedure

1) Pipet 10 ml of ammonium sulfate solution (0.12 mg/ml) into a distillation flask. Add water and boiling stones.
2) Distill sample under the same conditions used for the nitrogen determination procedure. See Nitrogen Determination - CA-1.

Calculation

$$\% \text{ recovery} = \frac{V \times N \times 14.01 \times 100}{B \times C}$$

$$= \frac{V \times N \times 14.01 \times 100}{10 \text{ ml} \times 0.12 \text{ mg/ml}}$$

N = Normality of sulfuric acid.

V = Volume of H_2SO_4 used for titration.

B = mls of ammonium sulfate used.

C = Concentration of ammonium sulfate solution (mg/ml).

14.01 = Molecular weight of Nitrogen.

INSTRUCTIONS FOR CARE OF KJELDAHL DIGESTION SYSTEM

- The system should be cleaned after every 100 samples or once a month.
- Remove and wash all glass parts (trap flask, digestion heads, etc.)
- Replace the 20% NaOH solution in fume trap once a month. Dissolve 200 g of NaOH in one liter of distilled water. Fill fume trap.

CA-1

NITROGEN AND PROTEIN DETERMINATION

ASSAY_____ LAB TECHNICIAN_____

THAM a)_____ b)_____ c)_____ d)_____ average_____normality

AMMONIUM SULFATE a)_____ b)_____ average_____normality

BLANK a)_____ b)_____ average_____

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
EDTA								

FIGURE 12

DETERMINATION OF MOISTURE - ONE HOUR METHOD

Moisture content is determined as loss in weight of a sample when heated under specific conditions. The following method should only be used if one can adhere to the strict temperature and time requirements specified in the procedure. The drying oven used must be maintained at the proper temperature (130°C) between analyses.

Apparatus

- Salton Quick Grinder or equivalent.
- Drying oven (130°C).
- Aluminum moisture dishes with lids, 55 mm diameter, 15 mm height.
- Metal tongs or rubber finger insulators.
- Analytical balance (accurate to 1 mg).
- Desiccator.

Procedure

1) Label aluminum moisture dishes.
2) Place clean dishes in drying oven (130°C) for 1 hour.
3) Transfer to a desiccator and let cool. After cooling quickly weigh moisture dish. Record wt. (W_1).
4) Weigh 1.5-2.0 g of finely ground sample into aluminum moisture dish. Ground grain should pass through 0.9 mm (20 mesh) screen. Record exact weight of sample + dish (W_2).
5) Place dish + sample in 130°C drying oven (uncovered) for one hour.
6) Cover dish while still in oven, transfer to desiccator, and weigh soon after reaching room temperature.
   Record new weight (W_3)

Calculation

$$\% \text{ moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

W_1 = wt. moisture dish (g).
W_2 = wt. moisture dish + sample before drying (g).
W_3 = wt. moisture dish + sample after drying (g).

Reference

Official Methods of Analysis of the Association of Official Analytical Chemists, 1984. 14th edition. Association of Official Analytical Chemists, Inc. 1111 North Nineteenth Street, Suite 210, Arlington, VA 22209 USA.

DETERMINATION OF MOISTURE - OVERNIGHT METHOD

If the strict temperature and time requirements of the one hour method (CA-2a) cannot be adhered to, the following procedure should be used.

Apparatus

- Salton Quick Grinder or equivalent. Ground grain should pass through 0.9 mm (20 mesh) screen.
- Drying oven (105°C).
- Aluminum moisture dishes with lids, 55 mm diameter, 15 mm height.
- Metal tongs or rubber finger insulators.
- Analytical balance (accurate to 1 mg).
- Desiccator.

Procedure

1) Label aluminum moisture dishes.
2) Place clean dishes in drying oven (105°C) for 1 hour.
3) Transfer to a desiccator and let cool. After cooling quickly weigh moisture dish. Record wt. (W_1).
4) Weigh 1.5-2.0 g of finely ground sample into aluminum moisture dish. Ground grain should pass through 0.9 mm (20 mesh) screen. Record exact weight of sample + dish (W_2).
5) Place dish + sample in 105°C drying oven (uncovered) overnight (18-24 hours).
6) Cover dish while still in oven, transfer to desiccator, and weigh soon after reaching room temperature.
   Record new weight (W_3)

Calculation

$$\% \text{ moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

W_1 = wt. moisture dish (g).
W_2 = wt. moisture dish + sample before drying (g).
W_3 = wt. moisture dish + sample after drying (g).

Reference

Official Methods of Analysis of the Association of Official Analytical Chemists, 1984. 14th edition. Association of Official Analytical Chemists, Inc. 1111 North Nineteenth Street, Suite 210, Arlington, VA 22209 USA.

DETERMINATION OF ASH

Ash is inorganic residue resulting from incineration of organic matter.

This procedure is useful for:

1) Preparing samples for mineral analysis.
2) Determining proportion of bran to endosperm in selected grain varieties since mineral content of bran is 20 times that of endosperm.
3) Indicating thoroughness of separation of bran from the rest of the grain during mechanical or manual decortication.

Material

- Muffle furnace (600°C)
- Porceline crucibles
- Metal tongs
- Analytical balance (accurate to the nearest 0.0001 g)
- Desiccator, with magnesium perchlorate desiccant
- Grinder

Procedure

1) Label crucibles
2) Place crucibles in muffle furnace (600°C) for 1 hour. Transfer to desiccator and let cool. To avoid moisture absorption, weigh quickly. Handle crucible with metal tongs.
3) Weigh 3.0-5.0 g of finely ground sample which can pass through a 0.9 mm (20 mesh) screen into each crucible.
4) Place crucibles in the muffle furnace (600°C) overnight.
5) Transfer crucibles to a desiccator and let cool. Weigh samples quickly to avoid moisture absorption.

Calculation

$$\% \text{ Ash} = \frac{\text{wt. (g) of crucible and sample before incineration} - \text{wt. (g) of crucible and sample after incineration}}{\text{sample wt. (g)}} \times 100$$

For adjusting % ash value to desired moisture basis use formula in Appendix I.

References

Pomeranz Y. and C. Meloan. 1978. Food Analysis: Theory and Practice (Revised Edition). AVI Publishing Company Inc., Westport, Connecticut p. 552.

Official Methods of Analysis of the Association of Official Agricultural Chemists. 1965. 10th Edition. Association of Official Agricultural Chemists, P.O. Box 540, Benjamin Franklin Station, Washington, D.C.

CA-2

DATE_____ LAB TECHNICIAN_____

DETERMINATION OF MOISTURE

SAMPLE	WT	CRUCIBLE WT	WT. OF CRUCIBLE AND SAMPLE	WT AFTER DRYING	$\%H_2O$
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

FIGURE 13

CA-3

DATE_____ LAB TECHNICIAN_____

DETERMINATION OF ASH

SAMPLE	WT	CRUCIBLE WT	WT. OF CRUCIBLE AND SAMPLE BEFORE INCINERATION	WT AFTER INCINERATION	%ASH
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

FIGURE 14

DETERMINATION OF OIL

This method can be used to gravimetrically determine oil content of a sample or to defat a sample when fat soluble materials may interfere with analysis.

Materials

- Salton Quick Grinder or Udy Cyclone Mill
- Extraction Thimbles
- Soxhlet extraction apparatus
  Round bottomed flasks
  Rotary Evaporator
- Drying oven
- Analytical balance
- Desiccator

Reagents

- Hexane (b.p. 69°C) or Petroleum Ether (b.p. 35-60°C)

Procedure

1) Grind sample to pass through a 0.4 mm mesh screen. If a vacuum oven is available, ground sample should be dried in a vacuum oven at 95-100°C under pressure not to exceed 100 mm Hg for 5 hours.

2) Weigh 5-10 g of sample into extraction thimble. Put degreased cotton glasswool in extraction thimble to cover sample.

3) Place thimble with sample into Soxhlet extractor.

4) Dry round bottom flasks at 103°C and cool in a desiccator. Weigh to the nearest mg.

5) Pour approximately 175 ml of solvent into round bottomed flask (hexane or petroleum ether).

6) Place on hot plate, and attach to Soxhlet extraction apparatus.

7) Turn on water source for the cooling system.

8) Adjust heat until solvent is boiling moderately.

9) After 18-24 hours, stop extraction process and leave to cool.

   For peanuts: Grind and dry peanuts. After 4 hours of extraction, remove the thimble and air dry until the majority of solvent has evaporated.

   Empty sample into grinder and grind as finely as possible. Quantitatively replace sample into extraction thimble and continue with extraction for 12-20 more hours. Leave to cool.

10) Collect all solvent in round-bottomed flask.

11) Attach round bottom flask to the rotary evaporator and evaporate off the major portion of solvent.

12) Evaporate last traces of solvent by drying flask in a drying oven (103°C).

13) Cool flask in a desiccator.

14) Weigh flask.

15) Replace flask into drying oven for 10-15 minutes.

16) Cool in desiccator.

17) Weigh flask. Difference between the two weighings must be within 10 mg. If not, dry sample again for 10 minutes until difference between consecutive weighings is within 10 mg. Use last weight for calculations.

Calculation

$$\% \text{ oil} = \frac{(P_1 - P_o) \times 100}{\text{sample wt.}}$$

P_1 = flask weight + oil (last weight)

P_o = flask weight

For adjusting % oil value to desired moisture basis use formula in Appendix I.

Reference

Guiragossian, V.Y., S.W. Scoyoc, and J.D. Axtell. 1977. Chemical and Biological Methods for Grain and Forage Sorghum. Department of Agronomy, Purdue University, West Lafayette, IN 47907.

CA-4

DATE _____ LAB TECHNICIAN _____

DETERMINATION OF OIL

SAMPLE	WT	FLASK NO	WT OF FLASK	WT OF FLASK AND OIL	WT OF OIL	%OIL
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

FIGURE 15

BLEACH TEST - DETERMINATION OF TESTA LAYER

Because tannins are predominantly found in the pericarp and pigmented testa layer, sorghums with brown and red pericarps that include a testa are usually high tannin sorghums. The following procedure is a means of identifying presence of a testa layer. Selection of plants without a testa should lead to development of populations low in tannin.

Materials

- Water Bath (60 - 70°C)
- Test tubes (16 x 150 mm)
- Test tube rack
- Erlenmeyer flask (125 ml)
- Graduated cylinder (100 ml)
- Spatula
- Magnetic stir plate
- Stir bar
- Balance
- Pipet (10 ml)
- Vortex mixer
- Screen

Reagents

- 60% NaOCl (commercial bleach)
- KOH (potassium hydroxide pellets)

KOH/Bleach solution

Prepare a KOH/bleach solution with a concentration of 1.0 g KOH/5 ml bleach. When analyzing 10 samples prepare the solution as follows: pour 100 ml of bleach into a 125 ml Erlenmeyer flask. Add a stirring bar and mix the bleach on a stirring plate. Weigh 20.0 g KOH pellets and slowly add to the bleach. Continue stirring until the KOH is completely dissolved.

Procedure

1) Turn on water bath and regulate the temperature between 60°C and 70°C.
2) Place test tubes in test tube rack, and label one tube for each sample.
3) Put 50 kernels (without glumes) in each tube.
4) Add 10 ml of KOH/bleach solution to each tube.
5) Place test tube rack with tubes into water bath (60-70°C) for 15 minutes.
6) After 15 minutes, wash each sample in a screen under a water faucet.
7) Place the washed grains on labeled filter papers.
8) Observe washed kernels. Kernels containing a testa have a predominantly dark brown color. Kernels without a testa have the same color as it's endosperm (white or yellow).

9) Place a (+) sign on data sheet next to tested variety if it conains a testa and a (-) sign if it does not.

Reference

Guiragossian, V.Y., S.W. Scoyoc, and J.D. Axtell. 1977. Chemical and Biological Methods for Grain and Forage Sorghum. Department of Agronomy, Purdue University, West Lafayette, IN 47907.

CA-5

DATE_____ LAB TECHNICIAN_____

BLEACH TEST - DETERMINATION OF TESTA LAYER

SAMPLE	TUBE	TESTA

FIGURE 16

RAPID TANNIN ANALYSIS

This tannin analysis method provides a rapid and convenient visual estimation of quantity of tannin present in sorghum grain, without use of instrumentation and with a minimum of glassware. It is based on reduction of ferric ions to ferrous ions by tannins and other polyphenols, followed by formation of a ferricyanide - ferrous complex. The colored product (commonly known as Prussian blue) absorbs maximally at 720 nm. This assay measures not only tannins but all phenols present, however, the method has proved useful since in high tannin sorghum most of the phenols are tannins. Because of the simplicity and rapidity of this test, it can be used for screening a large number of samples.

Materials

- Erlenmeyer flasks (250 ml)
- Graduated cylinder (250 ml)
- Pipet (10 ml)
- Measuring spoon (2 ml, approx. 0.7 g)
- Volumetric flask (250 ml)
- 3 Volumetric flasks (1,000 ml)
- Filter paper
- Funnel
- Flask (1,000 ml)

Reagents

- $FeCl_3$ (0.1 M)

Dissolve 29.0 g of hydrated $FeCl_3$ or 16.3 g of anhydrous $FeCl_3$ in a one liter volumetric flask with distilled water. Dilute to volume with HCl (0.1 M). Filter solution 3 times by gravity to remove the undissolved particles. Solution should be yellow.

- HCL (0.1 M)

Pipet 8.3 ml of concentrated HCl into a one liter volumetric flask. Dilute to volume with distilled water.

- $FeCl_3$ (0.008 M)

Pipet 20 ml of $FeCl_3$ solution (0.1 M) into a 250 ml volumetric flask. Dilute to volume with distilled water.

- K_3 $(CN)_6$ - (0.1 M)

Dissolve 32.9 g of $K_3Fe(CN)_6$ solution (0.1 M) in a one liter volumetric flask. Dilute to volume with distilled water.

Procedure

1) Using a 2 ml (approx. 0.7 g) measuring spoon, scoop up finely ground sorghum grain sample. Level off spoon without packing and place into a 250 ml flask. If all samples including low tannin cultivars give too dark a color, cut the sample size in half and repeat.

2) Add 200 ml of $K_3Fe(CN)_6$ solution (0.004 M) and swirl.

3) Add 10 ml of $FeCl_3$ solution (0.008 M). Swirl and observe change in color.

4) Classify samples into following groups:

COLOR	GROUP	TANNIN LEVEL	SOLUBILITY OF TANNINS IN WATER	RELATIVE NUTRITIONAL VALUE
Yellow	I	None	Non-soluble	High
Light green	I	Low	Non-soluble	High
Dark green	III	Intermediate	Soluble	Low
Dark blue	III	High	Soluble	Lowest

5) Use a standard to verify the results.

Standard sample	Color	Group
BR 64	Dark blue	III
½ MSB	Light green	I
ISO469	Yellow	I

Reference

Price, M.L. and L.G. Butler. 1977. Rapid visual estimation and spectrophotometric determination of tannin content of sorghum grain. Department of Biochemistry, Purdue University, West Lafayette, Indiana, 47907, J. Agric. Food Chem.

CA-6

DATE_____ LAB TECHNICIAN_____

RAPID TANNIN ANALYSIS

SAMPLE	SOLUTION COLOR	TESTA	GROUP	RELATIVE NUTRITIONAL VALUE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

FIGURE 17

TANNIN ANALYSIS (VANILLIN-HCl)

Tannins are polyphenolic compounds found in sorghum which, by complexing with the grain's proteins, reduce it's nutritional value. Along with lowering nutritional value, they can impart an astringent flavor which may reduce palatability. Tannins are predominantly found in the pericarp and pigmented testa layer, therefore, sorghums with brown or red pericarps that include a testa are usually high-tannin sorghums.

The vanillin-HCl procedure of Burns is based on acid catalyzed addition of vanillin to flavanols and their polymers, as well as addition to other polyphenolic compounds such as dihydrochalcones and flavonones. These reactions can be detected by a color change with maximum absorbance at 500 nm.

In sorghum, a number of compounds other than condensed tannins may give a positive vanillin reaction, moreover, not all of the condensed tannins can be extracted and assayed. Thus, determination of absolute levels of condensed tannin is not possible. This method however, is useful as a relative measure of tannin in sorghum grain and has been found to produce results that are highly correlated with nutritional values.

Materials

- 5 Erlenmeyer flasks (50 ml)
- Erlenmeyer flask (250 ml)
- Stoppers for Erlenmeyer flasks
- 7 volumetric flasks (100 ml)
- 3 volumetric pipets (5, 10, 50 ml)
- 2 volumetric pipets (25 ml)
- Test tubes
- Test tube rack
- Parafilm
- Spectophotometer (500 nm)
- Balance
- Horizontal agitator

Reagents

- Vanillin
- (+) catechin
- Methanol
- HCl (12 N, d = 1.18)
- Vanillin/HCl Solution (for standards and samples)

Prepare the flowing mixture immediately before use :

1 part of 8% concentrated HCl in : methanol (vol/vol)

1 part of 2% vanillin in methanol (wt/vol)

To prepare a solution for 5 standard solutions and 5 samples : pipet 8 ml of concentrated HCl into a 100 ml volumetric flask and dilute to volume with methanol. In another 100 ml volumetric flask, dissolve 2 g of vanillin in 100 ml of methanol. Mix the two solutions. The vanillin/HCl solution can not be used if traces of red color or particles are present.

- Methanol/HCl Solution (for blanks)

Because sorghum methanol extracts and standard solutions are colored even before addition of vanillin, a blank containing the solution to be tested and reagents without vanillin must be run for each sorghum variety and standard concentration. This will assure that % transmission reading will only be a measure of color due to vanillin-tannin complex. To prepare blank solvent, pipet 4 ml of conc. HCl into a 100 ml volumetric flask and dilute to volume with methanol.

Standard solutions

Prepare in a 200 ml volumetric flask, a solution of 200 mg catechin in 200 ml of methanol. Label the flask 1.00 mg/ml. To prepare the remaining standard solutions, place 5, 10, 25 and 50 ml of the catechin solution (1 mg/ml) in each volumetric flask of 100 ml. Dilute to volume with methanol, and label the flasks 0.05, 0.10, 0.25 and 0.50 mg/ml respectively. The 5 standard solutions are:

0.05 mg catechin/ml methanol
0.10 mg/ml
0.25 mg/ml
0.50 mg/ml
1.00 mg/ml

These 5 standard solutions can be saved for several months in a refrigerator.

Procedure

1) Weigh 0.5 g ± 3 mg of ground sample which can pass through a 0.40 mm screen into a 50 ml Erlenmeyer flask.
2) Add 25 ml of methanol with a volumetric pipet.
3) Place on horizontal agitator and agitate for 15 minutes at room temperature.
4) Label 2 test tubes for each standard solution, 2 test tubes for each sample and a blank tube for each standard and sorghum variety being tested.
5) Turn on the spectrophotometer one hour before use and adjust to 500 nm. After one hour, adjust gain so that the machine reads zero percent transmission.
6) After 15 minutes, add 1 ml of each standard solution to appropriate standard tubes, 1 ml of each sample to 2 sample tubes and 1 ml of each variety to a blank tube. Rinse pipet between each sample with the solution about to be used.

7) Solutions must be read in the spectrophotometer at exactly 20 minutes so this part of the procedure is best done with two lab techs. The color of the solution changes with time.
8) Add 5 ml of vanillin/HCl solution into the first standard tube and mix using parafilm to cover the tube. After one minute, add 5 ml to the next standard tube and mix. Continue to add vanillin/HCl solution to all the standard and sample tubes. For blank tubes, continue to fill in one minute intervals, but use methanol/HCl solution.
9) After 20 minutes, the 2nd lab tech should pour the standard tube into the spectrophotometer cuvette.
10) Place the cuvette into the spectrophotometer.
11) Read the % transmission at 500 nm.
12) Proceed to read the remaining solutions at 1 minute intervals.
13) In between each reading, rinse the cuvette with Methanol/HCl solution.

Calculation

1) To calculate % transmission readings, subtract sample blank reading from sample reading. This % transmission value can be converted to optical density by using the conversion table (Appendix VII) or by using the following formula:

$$\text{Optical Density} = 2 - \log_{10} T$$

2) Draw standard curve on a graph with a vertical scale of optical density (1/100) and a horizontal scale of catechin concetration (mg/ml) (see figure).
3) Calculate standard curve slope.
4) Calculate concentration in catechin equivalents for each sample:

$$\text{catechin equivalents} = \frac{5 \times (\text{average optical density})}{\text{standard slope curve}}$$

References

Earp, C.F., J.O. Akingbala, S.H. Ring and L.W. Rooney. 1981. Evaluation of several methods to determine tannins in sorghums with varying kernel characteristics, Cereal Chemistry 58 (3) : 234-238.

Guiragossian, V.Y., S.W. Scoyoc, and J.D. Axtell. 1977. Chemical and Biological Methods for Grain and Forage Sorghum, Department of Agronomy, Purdue University, West Lafayette, IN 47907.

Burns, R.E. 1963. Methods of tannin analysis for forage crop evaluation. Georgia Ag. Exp. Tech. Bull. NO.32 : 1-14.

Sarkar, S.K. and R.E. Howarth. 1976. Specificity of the vanillin test for flavanols, J. Agric. Food Chem 24 : 317.

Price M.L., S. VanScoyoc, and L.G. Butler. 1978. A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. J. Agric. Food Chem. 26(5) : 1214-1218.

CA-7

DATE_____ LAB TECHNICIAN_____

TANNIN ANALYSIS

SAMPLE	SAMPLE WT	WT OF FLASK	WT OF FLASK AND SAMPLE
1			
2			
3			
4			
5			

STANDARD

CATECHIN CONCENTRATION mg/ml	BLANK		SAMPLE A		SAMPLE B	
	%T	O.D.	%T	O.D.	%T	O.D.

STANDARD CURVE SLOPE_____

SAMPLE	BLANK		TUBE A		TUBE B		AVERAGE	CATECHIN
	%T	O.D.	%T	O.D.	%T	O.D.	O.D.	EQUIVAL.
1								
2								
3								
4								
5								

FIGURE 18

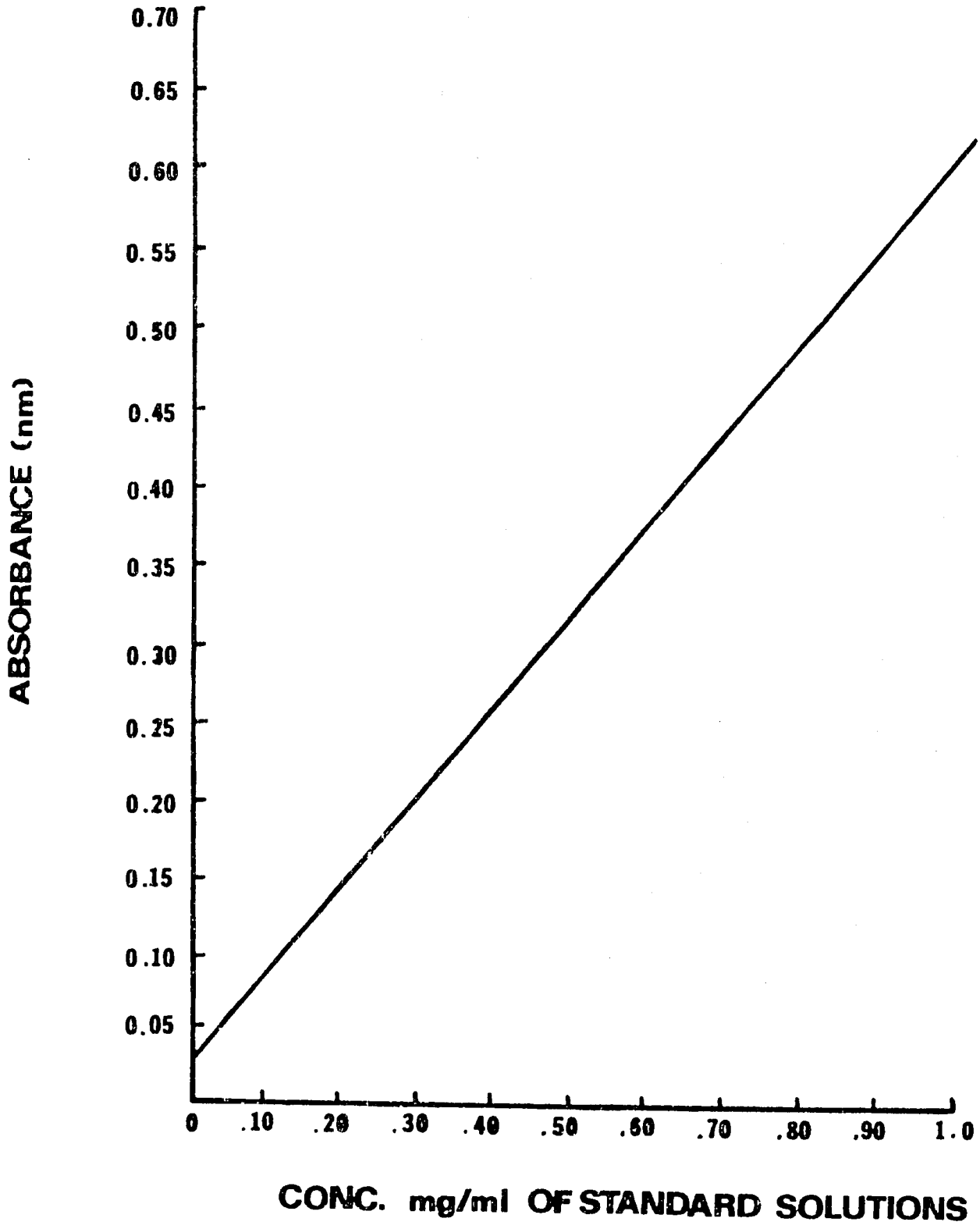

ABSORBANCE (nm)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.0
CONC. mg/ml OF STANDARD SOLUTIONS

FIGURE 19

DETERMINATION OF TOTAL PHOSPHORUS

The following procedure is for spectrophotometric determination of phosphorus. Ammonium molybdate reacts with phosphorus contained in the sample to form phosphomolybdate. This complex is then reduced by ascorbic acid with antimony serving as the catalyst. Reduced phosphomolybdate complex has an intense blue color. An absorbance peak exists at 700 nm and it would be best to take an absorbance reading at this wavelength. Some spectrophotometers, however, need a red filter and the appropriate phototube to make any measurements in the region greater than 600 nm. If this is the case, take readings at 500 nm.

Materials

- Beaker (125 ml)
- Beaker (500 ml)
- Test tubes (150 mm x 23 mm)
- Volumetric flask (250 ml)
- Volumetric flask (500 ml)
- 2 volumetric flask (1 liter)
- 6 volumetric flasks (100 ml)
- Sample volumetric flasks (25 ml)
- Sample volumetric flasks (100 ml)
- Graduated pipets (10 ml, 20 ml, 25 ml)
- Graduated Cylinders (50 ml, 200 ml)
- 2 Graduated Cylinders (500 ml)
- Volumetric pipet (4 ml)
- Grinder
- Hot plate with metal tube holder
- Balance
- Spectrophotometer
- Cuvettes

Reagents

Ammonium Molybdate [$(NH_4)_8MO_7O_{24}$]

In a beaker, dissolve 6 g of ammonium molybdate in 125 ml of distilled water.

Potassium antimony tartrate ($KSbOC_4H_4O_8$)

Dissolve 0.1454 g of potassium antimony tartrate in 50 ml of distilled water.

Sulfuric Acid (5 N)

In a 500 ml volumetric flask, pipet 74 ml of conc sulfuric acid. Dilute to volume and let cool.

Solution A: Ammonium Molybdate/Potassium antimony tartrate/Sulfuric Acid

In a one liter volumetric flask, mix 125 ml of ammonium molybdate solution, 50 ml of the potassium antimony tartrate solution, and 500 ml of sulfuric acid. Dilute to volume with distilled water.

Ascorbic Acid

Dissolve 1.848 g of ascorbic acid in 350 ml of solution A. prepare immediately before use. This is now referred to as the Murphy-Riley Reagent.

Perchloric Acid/Nitric Acid Solution

Mix 500 ml of nitric acid with 250 m of perchloric acid.

Standard Solutions (KH_2PO_4)

500 ppm P: Dissolve 2.197 g of potassium dihydrogen phosphate (KH_2PO_4) in 300 ml of distilled water containing 10 ml. of HCl.

Transfer to a one liter volumetric flask and dilute to volume. Keep in a polyethylene container.

5 ppm P: Pipet 25 ml of the 50 ppm solution in a 250 ml volumetric flask. Dilute to volume.

To prepare the 5 standard solutions, transfer each of the following quantities into a 100 ml volumetric flask. Dilute to volume.

Concentration (ppm P)	ml of the 5 ppm solution in 100 ml of water
0.50	10
0.75	15
1.00	20
1.25	25
1.50	30

Transfer solutions to polyethylene containers

Procedure

1) Turn on spectrophotometer one hour before use.

Extraction

2) Grind sample to a fine flour
3) Weigh 0.15 g into a dry tube
4) Add 6 ml the $HClO_4/HNO_3$ solution. Cover and leave overnight.
5) Transfer to a heating block (130° - 140°C) for 4 hours (until a volume of 0.5 ml of obtained)

Decoloration

6) Add 20 ml of distilled water and transfer solution to a 100 ml volumetric flask. Dilute to volume with distilled water.
7) With volumetric pipet, transfer 2 ml of this solution to a 25 ml volumetric flask. Add 10 ml of distilled water.
8) Add 4 ml of Murphy Riley Reagent with volumetric pipet, and dilute to volume with distilled water. Mix well.
9) Leave for 15 min.

Adsorption Reading

10) After 15 minutes, pour blank into cuvette, and place it in spectrophotometer.
11) Read % transmission at 500 nm. Adjust the transmission to zero with the gain knob.

    Note: % transmission readings are best taken at 700 nm, however, if a red filter and appropriate phototube is not available take reading at 500 nm (Read Spectrophotometer Manual)

12) Proceed to read each solution at 500 nm, and record results on data sheet.

Calculations

1) Calculate optical density from % transmission readings or use conversion table (Appendix VI).

2) Draw standard curve on a graph with a vertical scale of optical density (1/100) and a horizontal scale of phosphorus concentration (ppm)

3) Determine phosphorus concentration (ppm) from standard curve.

$$\% P = \frac{[\text{P concentration (ppm)}]\ [\text{dilution factor}]}{\text{sample wt.}}$$

$$\% P = \frac{[P \text{ concentration (ppm)}]\ [0.05]}{\text{sample wt.}}$$

References

JUO, A.S.R. 1978. Perchloric Acid digestion of plant materials for P, Ca, Mg, Fe, Zn and other element. Selected methods for soil and plant analysis. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Methods of analysis A.O.A.C.

Murphy, J. and J.P. Riley. 1962. A Modified single solution method for the determination of phosphate in natural water. Annal. Chim. Acta 27:31-36.

PEPSIN DIGESTIBILITY

The quality of food protein is determined by its amino acid composition and its digestibility, with protein digestibility being determined by percentage of protein that may be absorbed in the form of amino acids. The enzyme pepsin is used to simulate digestibility in humans. This method, developed by Mertz et al. (1984) is less time consuming and less expensive than rat feeding studies and has been reliable in showing digestibility differences between sorghum and other grains. It may also be useful for comparing digestibility levels of different sorghum food preparations as was done by Johnson (1981), who compared three types of porridge found in West Africa. The original procedure has been modified for use in developing countries where expensive equipment may not be available, however, it is of utmost importance that the procedure be executed in a consistent and reproducible manner.

Materials

- Screen (0.4 mm)
- Salton Quick Grinder or Udy Cyclone Mill
- Polyethylene centrifuge tubes (50 ml)
- Agitating water bath or water bath
- Beaker (600 ml, 1000 ml, 2000 ml)
- Erlenmeyer flask (125 ml)
- Volumetric flask (1000 ml)
- Graduated cyclinder (10 ml)
- Magnetic stir plate
- Balance
- Stir bar
- pH meter
- Refrigerated centrifuge or centrifuge with metal tube holders
- Buchner funnel (43 mm)
- Filter paper (Whatman No. 3)
- Metal tongs

Reagents

- Pepsin (Activity: 1200-2000 units/mg protein)
  Recommended Source: Sigma Chemical Co., No. P-7000.

- KH_2PO_4 Solution (0.1 M) pH 2

Weigh 13.6 g of potassium dihydrogen phosphate (KH_2PO_4) into one liter beaker. Add approx. 750 ml of distilled water and dissolve. Place pH meter electrodes into solution and adjust pH to 2 with concentrated HCl (10-13 ml). Put this solution into a 1 liter volumetric flask, and dilute to volume with distilled water.

- KH_2PO_4/Pepsin Solution (1.5 mg/ml)

In a 250 ml beaker, pour 80 ml of the KH_2PO_4 buffer. Add 0.15 g of pepsin. Mix on stir plate for 3 hours. Transfer solution to a 100 ml volumetric flask, and dilute to volume with distilled water. Solution must be made immediately before use.

Procedure

1) Place 0.200 g of flour which can pass through a 0.4 mm screen into a 50 ml polyethylene centrifuge tube. Include a tube without sample to be used as blank. If running analysis on uncooked sample, skip steps 2 and 3.

2) Add 2 ml of distilled water and agitate by hand.

3) Place tube in boiling water bath for 20 min. Remove tubes.

4) Add 25 ml of KH_2PO_4/Pepsin solution to each tube. First, add 15 ml of solution, break up cake with stirring rod and rinse stirring rod with remaining 10 ml of solution.

5) Place tubes in agitating water bath (37°C) for 2 hours or place in a water bath (37°C) and agitate by hand every 15 minutes.

6) After 2 hours, place tubes in refrigerated centrifuge (4°C). If a refrigerated centrifuge is not available, place tubes in an ice bath for 30 minutes. Cool the metal centrifuge tube holders in the ice bath also.

7) Centrifuge tubes at 4,800 x g for 15 minutes.

8) Remove the supernatant with a pasteur pipet and discard.

9) Add 5 ml of buffer solution (KH_2PO_4) to each tube. Break-up residue with a stirring rod and rinse rod with 5 ml more of buffer.

10) Recentrifuge for 15 minutes at 4,800 x g rpm.

11) Remove the supernatant with a pasteur pipet and discard.

12) Filter residue with Whatman No. 3 filter paper in a 43 mm Buchner funnel. Rinse the tube with 2-5 ml portions of buffer onto the filter paper.

13) Envelope the residue in filter paper and put this into a Kjeldahl digest on flask. Hands should be clean for this operation. Dry in oven at 100°C.

Digestion

1) In dry Kjeldahl flask containing filter paper and filtrate, introduce 10 ml of conc. H_2SO_4 and 0.5 g of catalyst. Let stand for 30 minutes.

2) Continue with digestion, distillation and titration procedures of Nitrogen Determination - CA-1, but add 40 ml of NaOH (10 N) before distillation instead of, 15 ml.

3) Run a blank containing an empty filter paper, H_2SO_4 and catalyst for each series. Titrate and note the volume of H_2SO_4 used (Vo).

Calculation

The percentage of protein contained in sample after treatment with pepsin is pepsin indigestible protein.

$$\% \text{ undigested N} = \frac{(V - V_o) \times N \times 14.0 \times 100}{0.200 \times 1000}$$

$$\% \text{ digestible N} = \frac{\text{total \% N of untreated sample} - \% \text{ undigestible N}}{\text{total \% N of untreated sample}}$$

$$\% \text{ digestible P} = \% \text{ digestible N} \times 6.25$$

References

Mertz, E.T., M.M. Hassen, C. Cains Whittern, A. Kirleis, L. Tu and J. Axtell. 1984. Pepsin digestibility of proteins in sorghum and major cereals. Proc. Nat'l Acad. Sc. U.S.A. 81:1-2.

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CA-9

DETERMINATION OF NITROGEN AND PEPSIN DIGESTIBILITY

DATE_____ LAB TECHNICIAN_____

ASSAY_____

THAM a)_____ b)_____ c)_____ d)_____ average_____ normality_____

AMMONIUM SULFATE STANDARD a)_____ b)_____ average_____ % recovery_____

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
BLANK								

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
BLANK								
STANDARD								

FIGURE 20

PEPSIN DIGESTION METHOD

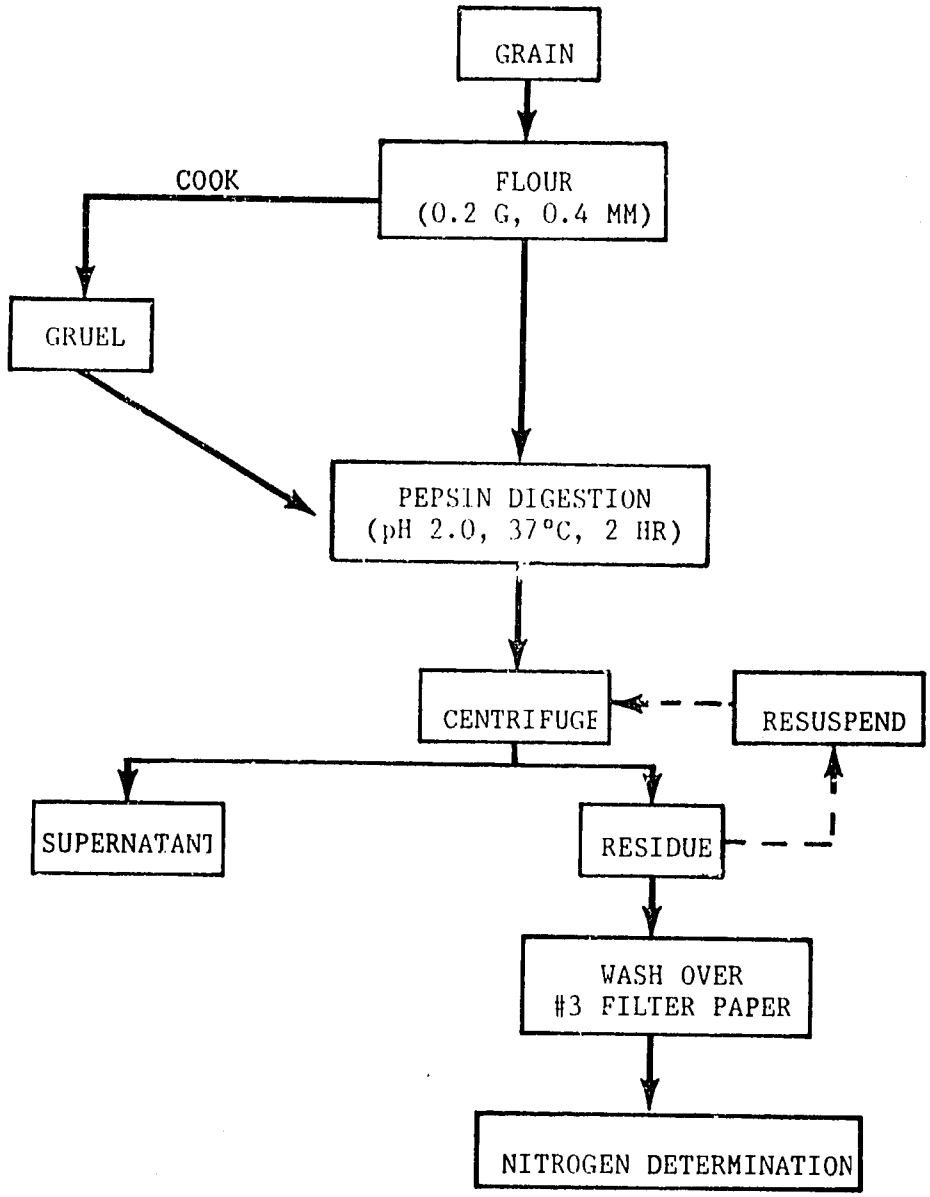

FIGURE 21

III. LABORATORY METHODS

C. FOOD QUALITY ANALYSIS

DEHULLING PROCEDURES IN WEST AFRICA

Grain hardness and ease of dehulling by either traditional or mechanical procedures are quality criteria that directly influence the acceptability of new and established sorghum cultivars. Since sorghum grains vary enormously in their dehulling quality, it is desirable to develop small-scale equipment and methodology for use in the laboratory to mimic the full scale dehulling methods in order to determine this quality characteristic and to prepare grain which is comparable to traditionally dehulled grain for small-scale laboratory food preparations.

Traditional Dehulling Methods

Traditional dehulling methods in West Africa are aided by the addition of water. The grain is placed in a wooden mortar (approx. 3/4 meter) and 20-25% water by weight is added. The grain is then pounded with a pestle until decortication is complete (10-20 minutes). The addition of water allows the bran layer to swell and become partially detached from the endosperm while pounding provides the abrasive action necessary to remove the bran layer from the endosperm.

Village-Scale Dehullers

One type of mechanical dehuller used in West Africa is the "Engleberg type" dehuller. It's horizontally mounted, cylindrical, metal disk with horizontal ridges separates the bran from the grain in a semi-moist dehulling process. Most models come from the Ivory Coast or China. Studies in Mali have shown that decorticated grain recovery from these dehullers is amazingly similar to that of traditional pounding.

Industrial-Scale Dehullers

Most industrial-scale mechanical methods of dehulling sorghum process the dry sorghum seed. Abrasive-type dehullers equipped with carborundums tones or emery-coated abrasive disks appear to be the most commonly used.

LABORATORY DEHULLING PROCEDURES

In order to mimic the locally dehulled grain in the laboratory, the Food Technology Laboratory of SRCVO in Mali have used the following small-scale dehullers. Although they have found some to be useful in preparing grain for small-scale food preparations, only the PRL Dehuller has been reliable in screening sorghum cultivars for endosperm recovery levels. For this reason, all laboratory testing to analyze grain dehulling characteristic are done with the PRL or by hand pounding 1 kg grain lots. The grain is pounded in a mortar by a Malien woman, sifted to separate decorticated grain from the fines, weighted and adjusted to a dry weight basis.

PRL Dehuller

The PRL Mini-Dehuller (Nutana Machine Company) has horizontally mounted resinoid disks at 3 cm intervals which remove the pericarp by an abrasive process. The machine holds up to 7 kilograms of grain but can easily mill samples as small as 1 2 kilograms. The whole grain is placed in the resinoid disk chamber, and the bran is removed by the fast turning action of the disks. After the grain is decorticated, the sample is removed and hand-screened to separate the fines from the dehulled grains.

Studies in Mali (Haidara and Coulibaly, 1985) have shown that milling times of 3 minutes for a two kilogram sample produce a dehulled grain that is similar to the traditionally dehulled grain in terms of grain recovery levels and tô acceptability. The disadvantage to this apparatus is that a minimum 1 kilogram sample must be used.

Modified Udy Cyclone Mill

The Udy Cyclone Mill is modified by Shepherd (1979) can be used on 5-25 g grain samples. The sample is fed to a turbine wheel that would normally spin at a very high speed, breaking the sample into pieces. A Rheostat is connected to the Udy Cyclone Mill to adjust the electrical current so the turbine wheel spins at a much slower speed and an abrasive action rather than a breaking action is obtained. The bran is then separated and hurled to the outside rim where it is carried away with the airflow through the screen and separated in the cyclone. The dehulled grain is then removed from the dehulling chamber to a collection cup with a vacuum. Although small samples can be run on this apparatus, only one sample at a time can be dehulled and reproducibility between replicates is poor.

TADD-Tangential Abrasive Dehulling Devise

The TADD was designed and built to simulate as closely as possible, the abrasive action produced in commercial sorghum dehullers. It is composed of a carborundum stone or resinoid disk, mounted horizontally beneath 5-12 sample cups. In operation, 5-10 g sample of grain are placed in each cup, the cover is fastened into position and the resinoid disk is rotated under the cups at 1725 rpm for the time set on the timer. The fines that are generated during dehulling exit underneath the cups and are swept out of the machine and into a fines collection bag by means of a built in fan. The dehulled samples are removed from the sample cups with a vacuum sample collector.

Studies by Riechert (1981) using a Simonds resinoid disk showed the TADD to be slightly more efficient than the PRL dehuller. He predicts that by changing the grit size and structure of the abrasive surface, it should be possible to closely mimic the properties of any abrasive-type large-scale dehuller.

The TADD is currently being used in Mali to prepare grain for small-scale food preparations in the laboratory. A milling time of 2-2½ minutes yields a dehulled grain that prepares into a tô with acceptability levels comparable to tô prepared from grain by traditional dehulling methods. The advantages of the unit include its multi-sample capability and high reproducibility.

References

Haidara M., Coulibaly S. and Scheuring J.F. Acceptabilité du Tô de Sorgho suivant le Decorticae Progessif des Grains. Atelier CRDI sur Les Aspects Techniques des Decortiqueses Abrasives § Disques, Dakar, Senegal, 2-7 March 1985.

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MAY GREUNWALD DYE PROCEDURE

The following procedure has been used to evaluate the degree of decortication of grains. Because of time required to carry out this analysis, it may not be useful for routine evaluations. However, it has been valuable for comparing decorticated grain from mechanical devices with manual decortication procedures.

A mixture of Eosin y and methylene blue dyes react with the pericarp and endosperm of the grain surface to show the extent of decortication. The endosperm stains pink, and the adhering pericarp stains blue.

Materials

- 2 Volumetric flasks (100 ml)
- 8 Beakers (200 ml)
- Wire mesh screen (1 mm)
- Paper towels

Reagents

- Eosin y dye
- Methylene blue dye
- Methanol, reagent grade

Solution preparation:

A. Methylene blue Dye

Place 1.0 gm of methylene blue in a 100 ml volumetric flask and fill to volume with methanol.

B. Eosin Y Dye

Place 1.0 gm of Eosin Y dye in another 100 ml volumetric flask and fill to volume with methanol.

C. May-Greunwald Dye

Make a 1:1 dye solution by mixing equal parts of these two dye solutions. To prepare a stable working solution, mix 1 part of the 1:1 dye solution with 3 parts methanol. Let this solution stand overnight and decant. This can be stored in a refrigerator for several weeks.

Procedure

1) Place 100 decorticated grains into a wire mesh net that is capable of being dipped into a 200 ml beakers.

2) Place an adequate quantity of the following solutions in a sequence of 8 beakers. Rinse the grain sample in each solution for one minute.

   a) distilled water
   b) dye solution
   c) methanol
   d) methanol
   e) methanol
   f) methanol
   g) methanol
   h) distilled water

   Avoid unnecessary contamination from one beaker to the next.

3) Blot the seeds dry with a paper towel trying not to rub of the dye. Once the kernels are dry, the dye is permanent. Remove the broken kernels from the sample.

4) Each of the dyed grains must be evaluated for the degree of decortication as a function of the tissue adhering to the grain. The grains are evaluated on their ventral face (to note the removal of germ) and their dorsal face (to note the removal of pericarp). This evaluation is quantified by rating the grains according to the following schema and adding the ratings of the two faces.

DORSAL SIDE			
RATING	COLOR	DEGREE OF DECORTICAGE	OUTERMOST LAYER
1	rose	well decorticated	Endosperm
2	dead white	↓	Aleurone
3	blue	↓	Mesocarp
4	translacent	↓	Intermediate
5	translucent white	dorsal side, undecorticated	Epicarp

VENTRAL SIDE		
RATING	COLOR	DEGREE OF DECORTICATION
1	rose	germ totally removed
2	blue or green	germ partially removed
3	uncolored	germ unremoved, ventral face undecorticated

Add together the ratings of all the dyed grains and divide by the number of grains to find the average rating.

References

Kanté A, Coulialy S., Scheuring J.F. et Niangado O., 1984. La facilité de décorticage du petit mil en relation avec les charactéristique du grain. Présenter au Symposium sur la Transformation Industrielle du Sorgho et des Millets.

Scheuring J.F. and L.W. Rooney. 1979. A staining Procedure to determine the extent of brain removal in pearled sorghum, Cereal chemistry. 56:6, 545-549.

SMALL-SCALE PREPARATION FOR ACID AND ALKALI TÔ

There are three types of thick porridge found in the Sahelian region of West Africa. In Niger, a neutral porridge called tuwo is prepared. The alkali porridge prepared in Mali, is called tô and its preparation only slightly differs from the acid tô made in Burkino Faso.

This small-sample cooking procedure was described by Da (1982) and Akingbala (1982) and has been used for predicting firmness, stickiness, color and storage properties. The acid tô laboratory preparation compares favorably in consumer evaluation results with the traditionally prepared tô in Burkina Faso in terms of texture, pH, taste and acceptability. The method is relatively simple and useful in reducing time and effort in screening for good tô quality sorghum.

Materials

- Udy Cyclone Mill or Salton Quick Grinder
- Modified Udy Cyclone Mill or TADD
- Balance
- 2 Beakers (150 ml)
- Beaker (250 ml)
- Graduated Cylinder (50 ml)
- Stirring Rod
- Hot Plate
- 2 Beakers (10 ml)

Reagents

- Lemon Juice Concentrate (Realemon Brand, Borden Inc., Columbus, Ohio, 43215, USA). Tamarind extract may be substituted at a concentration similar to large scale preparations.

- Potassium hydroxide (KOH)

Procedure

Flour Preparation

1) Pearl 10 gm of sample in a modified Udy Cyclone mill (Shepherd, 1979) or TADD to separate the dehulled grain from the bran and fines.
2) Mill the dehulled grain in a tô flour on a Udy Cyclone Mill or Salton Quck Grinder to pass through a 0.40 mm screen opening.

Acid tô (pH 4.6) Preparation

1) Mix 9.5 gm of flour, which has been measured on a dry weight basis, with 20 ml of distilled water.
2) In a 150 ml beaker, measure 20 ml of water and 1 ml of concentrated lemon juice.
3) Place lemon juice mixture on an electric hot plate set at maximum temperature and bring the solution to a boil.
4) Pour the flour slurry into the boiling solution with continuous stirring.
5) Add 5 ml of water to flour bowl to rinse out the remaining flour into the boiling solution.
6) Cook slurry for 5 minutes and then pour into two 10 ml beakers and set asid for testing.

Alkali tô (pH 8.8) Preparation

1) Mix 9.5 gm of flour, which has been measured on a dry weight basis, with 20 ml of distilled water.
2) In a 250 ml beaker, dissolve 45 g of KOH in 200 ml of distilled water (0.07 M).
3) Place the alkali solution onto an electric hot plate set at maximum temperature until boiling and bring the solution to a boil.
4) Pour the flour slurry into the boilin~ solution with continuous stirring.
5) Add 5 ml of water to the flour bowl rinse out the remaining flour into the boiling solution.
6) Cook slurry for 5 min and then pour into two 10 ml beakers and set aside for testing.

METHODS FOR EVALUATING TÔ FIRMNESS AND STICKINESS

Tô firmness

1) Remove tô from the 10 ml beakers and slice into 6 slices with an egg slicer. Discard the top and bottom slices.
2) Divide the remaining four slices into two (11.0 mm thick) sets of two slices each.
3) Measure the firmness of each set of tô slices with a precision "penetrometer" (Serial No. 11-Y-12, manufactured by Precision Scientific Company, Chicago, USA) calibrated in 0.1 mm divisions and equipped with a miniture size penetration cone, 8.3 g in weight and 3.3 cm in diameter.
4) Place the tô sample on a hard, flat surface under the cone.
5) Lower the cone until its tip touches the surface of the tô.
6) Release the cone by a lever and allow it to free fall into the tô.
7) Read the penetration of the cone into the cone on the dial 10 seconds after the fall of the cone.
8) Tô with a penetrometer reading of greater than 8.00 mm are rated as very soft. Intermediate readings are between 7.00 and 8.00 mm, and any tô with a reading of less than 7.00 mm is rated as firm.

Tô stickiness

Tô stickiness is measured on the same slices of tô used in the tô firmness determination. However, instead of two sets of two slices each, stickiness is measured on each slice of tô to give four replicates for the four tô slices. The apparatus used for measuring tô stickiness consists of a double pan balance, a buret, a laboratory jack and a water trough. A steel disk is attached to the bottom of the left scale pan with a steel rod. On the right scale pan is the water trough made of aluminum. To measure tô stickiness, the scale pointer is zeroed by the addition to, or removal of water from the trough. A slice of tô on a flat plexiglass surface is placed on the laboratory jack. The the jack is raised until there is contact between the tô and the steel disk. A good contact between tô and disk surfaces is assured by tapping the disk lightly. The pointer, displaced from zero by the contact between tô and disk surfaces, is zeroed again by raising or lowering the jack. Then water is added into the trough from the buret, at the rate of 14 ml/min. The addition of water to the trough displaces the pointer from zero. The ponter deflection is followed on a scale until the weight of water breaks the contact between the tô and disk surfaces. The position of the pointer just before the disk separates from the tô is recorded as the stickiness of the tô. The steel disk is wiped with a wet tissue and dried after each stickiness measurement. A nonsticky tô induces a deflection of less than 3.0, a moderately sticky tô deflects the pointer 3.0 to less than 4.0 and a very sticky tô has a deflection of greater than 4.0. Because of the subjective nature of this method, great care should be taken to standardize the method.

References

Da S. 1982, The relationship of tô quality to plant color and agronomic characteristics in sorghum bicolor (L.) Moench. Ph.D. Dissertation. Texas A&M University, College Station, TX 77843.

Akingbala J.O. 1982. Effects of physiochemical properties of sorghum starch and endosperm on the quality of traditional African food. Ph.D. Dissertation. Texas A&M University, College Station, TX 77843 (Diss. Abstr. 82-26057).

Shepherd, A.D. 1979. Laboratory abrasive decorticating mill for small grains. Cereal Chemistry 56:517-519.

Tô COLOR AND KEEPING QUALITY DETERMINATION

Tô keeping quality has been identified as an important quality parameter by the Food Technology laboratory in Mali. Its keeping quality is synonymous with gel stability and a thick porridge with unstable gel will exude water and become mushy with increasing storage time. Gel stability is a physical property which is characteristic of each flour type and can be measured without preparing a large scale batch of porridge which takes a minimum of 1 kg of grain. The following small-scale method was developed for use with alkali tô in Mali and has been successful in predicting keeping quality characteristics of local and introduced sorghum cultivars.

Materials

- Udy Cyclone Mill or Salton Quick Grinder
- Beaker (200 ml)
- Water Bath (100°C)
- pH meter
- Thermometer
- Metal Bowl
- Stir Rod

Procedure

Preparation

1) Grind 20 g of whole grain in a Udy Cyclone Mill or Salton Quick Grinder to pass through a 0.40 mm screen.
2) Mix flour with 125 ml of warm water in a 200 ml beaker.
3) Place the beaker in a boiling water bath with the water level at about 5 cm.
4) Introduce a pH meter electrode to monitor the pH.
5) Adjust porridge to the desired pH by the addition of NaOH (1 stock chip per 250 ml of water).
6) The paste is stirred for 20 min until becomes very stiff.
7) After cooking, the porridge is removed from the beaker and placed in a small metal bowl. At this time, porridge color can be evaluated. The bowl is covered with a piece of paper and allowed to stand overnight.

Color Determination

8) Press a small amount of porridge between two sheets of glass and place on an opaque surface so that light does not shine through the porridge. Evaluate the porridge color with the use of the Munsell Soil Charts.
9) The next morning, the porridge is turned upside-down and is evaluated for firmness using a scale of 1-5. 1 is the most firm and 5 is greul-like. A score of 3 or less indicates an acceptable keeping quality.

1-firm
2-still firm but sticky around edges
3-not stiff, but gel holds form
4-gel does not hold form
5-gruel-like

Note:

A variation in storage temperatures can affect keeping quality results. For this reason, steps should be taken to keep night time storage temperatures at the year-round average during the cold season. The Food Technology Laboratory in Mali has constructed a well-ventilated, metal box to hold samples overnight. The temperature is controlled with kerosene lamps placed in the box.

References

Sidibé, S. 1980. Accepabilité Culinaire comme un des Critères de Selection des Sorghos au Mali. Thèses. Institute Polytechnique rural, Katibougou, Mali.

Scheuring J. 1980. From Tô to Timbuctu: Cereal Quality work by ICRISAT in West Africa. Report submitted to the Joint Meeting of the UNDP-CIMMYT/ICRISAT Policy Advisory Committee. Patancheru, India, 14-18 Oct. 1980.

Munsell Soil Charts. 1975. Evanston, Illinois, USA: Soil Test Inc.

GEL SPREAD TEST

This test for gel consistency has proved successful in predicting certain food quality characteristics. A study by Murty and House (1980) showed that the corneousness of grain and the flour courseness were negatively correlated with spreading.

Taste panel assessments of ugali, a thick porridge of Eastern and Southern Africa, were associated with the gel spread results.

Materials

- Grinder
- Petri Dishes (20 mm x 5 mm)
- Beaker (200 ml)
- Beaker (500 ml)
- Vegetable Oil
- Hot plate
- Glass plate
- Ruler
- Refrigerator (10°C)

Procedure

1) Prepare petri dishes by smearing one drop of oil in each dish.
2) Grind sorghum samples into a fine flour. A consistant flour coarseness must be used for all samples.
3) Add 10 g of freshly ground flour to 70 ml of tap water. Mix to a slurry.
4) Add this slurry to 140 ml of boiling water and boil for approx. 10 minutes.
5) When bubbling and frothing stops, pour the porridge into a petri dish.
6) Cool in a refrigerator (10°C) for 3 hours.
7) After 3 hours, transfer the gel to a smooth glass surface by inverting the petri dish.
8) After 5 min. measure the diameter of the gel mass in mm.

GEL SPREAD = WIDTH OF GEL DIAMETER (mm)

Reference

Murty, D.S. and L.R. House. 1980. Sorghum Food Quality: Its assessment and improvement. Report submitted to the joint meeting of the UNDP-CYMMYT-ICRISAT Policy Advisory Patancheru, India, 14-18 Oct. 1980.

Murty D.S., H.D. Patil and L.R. House. 1981. Cultivar differences for gel consistency in sorghum. p. 289 - 293. In Proceedings for the International Symposium on Sorghum Grain Quality. ICRISAT Center, Patancheru, India, 28-31 Oct 1981.

SMALL SCALE COUSCOUS PREPARATION

Studies in Mali have shown that the most important quality criterion of Malian prepared couscous is the yield of the final product compared with the original flour. This small-scale couscous preparation has been used in Mali to detect the large varietal differences in couscous yield.

Materials

- Salton Quick Grinder or Udy Cyclone Mill
- Balance
- Beaker (100 ml)
- Graduated Cylinder (20 ml)
- Cotton Cloth
- Steaming apparatus: small perforated bowl
  small pot
- Hot plate
- Spoon

Procedure

1) Grind 20 g of whole grain in a Salton Quick Grinder or Udy Cyclone Mill to pass through a 0.40 mm screen.
2) Place whole grain flour in a beaker and mix approximately 12 ml of water with the flour until it is uniformly wetted. The quantity of water depends on the endosperm texture.
3) Place the flour in a piece of cotton cloth and place into a small perforated bowl over a small pot of boiling water. Be sure to remove all flour from beaker.
4) cover the perforated bowl, and leave for 3 minutes.
5) Remove the perforated bowl and break the steamed flour into small pieces with a spoon.
6) Continue to steam flour for another 2 minutes.
7) After 2 minutes remove the flour and break-up the flour grain.
8) Sprinkle the flour with 20 ml of water and stir to obtain uniform wetting.
9) Steam the flour for another 2 minutes.
10) Remove the steamed flour and weigh immediately.

References

Sidibé, S., M. Diarra and J.F. Scheuring. 1981. Sorghum couscous: quality considerations. p. 110 - 112. In Proceedings from the International Symposium on Sorghum Grain Quality. ICRISAT Center, Patancheru, India 28-31 Oct 1981.

LOCATIONAL AND SEASONAL VARIATION

Because of the enormous influence that environmental conditions have on sorghum grain development, varietal screening for food quality should always be carried out on grain lots that have been grown under a variety of field conditions. Not only is it important that food quality evaluation studies be run on grain from multilocational field sites, but that the grain be obtained from those regions with the climatic conditions for which the grain is being breeded.

During the International Sorghum Food Quality Trials, 1979-1981, twenty-five sorghum varieties grown over a period of 3 years were sent from ICRISAT Center, India to Mali for testing of food quality characteristics. The grain from all 3 years was clean and sound, however, there were clear indications of year to year variation. Some varieties had poor quality in one year and excellent quality in another. The contrasts were particularly marked for keeping quality in several varieties.

Studies in Mali have found grain weathering and headbug damage to greatly affect alkali tô keeping quality. In the case of weathering, the rapidity and extent of the condition are enhanced by low fertility and post floral drought. Weathered grain is usually soft and floury and causes the tô of most introduced sorghums to lose their gel stability. Many of the local sorghums also lose gel stability due to weathering, but the effects aren't as pronounced. Headbug Tolerance Studies in Mali showed that grain damaged by the Eurystylus sp. also produced a chaffy grain and in turn a tô of unacceptable keeping quality. In all cases, the final tô colors of the bug damaged grain were darker than those of the undamaged grain.

REFERENCES

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Scheuring J.F., S. Sidibé and A. Kanté. 1981. Sorghum alkali tô quality considerations. p. 24 - 31. In Proceedings from the International Symposium on Sorghum Grain Quality. ICRISAT Center, Patancheru, India. 28-31 Oct 1981.

IV. APPENDIX

APPENDIX A

ADJUSTING ANALYTICAL VALUES TO DESIRED MOISTURE BASIS: For adjusting analytical values to a desired moisture basis use the following formula:

$$\frac{100 - \text{desired moisture basis}}{100 - \%\text{ "as is" moisture}} \times \text{analytical value on "as is" moisture basis} = \text{value at desired moisture basis}$$

"As is" refers to the sample as it is collected.

Calculation Example

An undried sample is found to have 12.0% protein content and a 15% moisture content. In order to adjust the protein measurement to a dry weight basis, do the following calculation.

$$\frac{100 - 0}{100 - 15} \times 12.0\% = \text{14.1\% Protein at 0\% moisture basis}$$

To adjust the protein measurement to a 14% moisture basis:

$$\frac{100 - 14}{100 - 15} \times 12.0\% = \text{12.1\% Protein at 14\% moisture basis}$$

APPENDIX B

MANAGEMENT OF DANGEROUS REAGENTS

ALL reagents that are volatile, flammable, toxic or corrosive must be used in a well ventilated hood.

1. Explosive (very volatile and flammable)

   Petroleum ether
   Diethyl ether
   Acetone

   Store away from flames and hot plates

2. Toxic

   Benzene
   Carbon tetrachloride
   Acetonitrile

   Avoid all contact to garments or hands

3. Corrosive

Conc. hydrochloric acid
Conc. sulfuric acid
Conc. nitric acid
Conc. ammonia
Glacial acetic acid

Immediately remove with an abundance of water.

DISPOSAL OF CHEMICAL WASTE

All of the above mentioned reagents and other dangerous chemical waste must be kept in a special reciprocal and must be disposed of at a well designed place.

1. Waste from the Kjeldahl analysis
2. Solutions - soils and plant extracts containing lead (Pb), mercury (Hg), selenium (Sc), chloride (Cl), zinc (Zn), cyanide and arsenic.
3. Pesticides, herbicides and fumigants

APPENDIX C

LABORATORY ACCIDENTS

A. Flammable Products

1. Acetone : Dilute by sprinkling with water to avoid the continuation of liquid burns.
2. Alcohol : see acetone.
3. Benzene : Use water to cool the bottles that are dangerous. Extinguish the flames with sand, soil, an extinguisher or carbon tertrachloride. Use a gas mask.
4. Carbon Tetrachloride : when an extinguisher or carbon tetrachloride is used on a fire in a confined space, the fire should be transferred outdoors if possible or the place where the fire is being extinguished should be immediately evacuated. Persons must not return to the place until the air is clear of all fumes.

These precautions should be observed without considering the means employed for extinguishing the fire in view that fire in a closed space rapidly produces a toxic atmosphere.

B. Corrosive Products

1. Hydrochloric acid : use an abundance of water, sodium or limestone and use a gas mask.
2. Nitric acid and the nitrogen oxides : alot of water, no sand or soil, use a mask.
3. Sulfuric acid : alot of water
4. Sodium hydroxide : alot of water
5. Potassium hydroxide : alot of water or dilute acid
6. Magnesium : no water, use sand or soil
7. Phosphorus : water and wet sand
8. Chlorine : sprinkle with water and use a mask.

APPENDIX D

FIRST AID

A. Care in cases of poisoning and intestinal burns

1. Acetic acid : magnesium chalk, soap, sugar
2. Hydrochloric acid : magnesium, carbonates, alkalins, ice
3. Nitric acid : magnesium, carbonates, alkalins.
4. Phosphoric acid : same as nitric acid
5. Sulfuric acid : same as hydrochloric acid plus soap or oil.
6. Arsenic : milk, market oil, uncooked egg, flour in water.
7. Mercuric chloride : zinc sulfate, egg white, fresh milk, table salt
8. Sodium hydroxide or potassium hydroxide : vinegar, lemon juice, orange juice, oil, milk.
9. Methanol : milk, egg white, flour in water, magnesium sulfate, clean stomach.
10. Carbon Monoxide or gas : replace fresh air immediately, artificial respiration, inhalation of ammonium.
11. Silver Nitrate : salt and water.

B. Skin Burns

1. General Care : In case of burns, rinse the burned area and place it in an ice bath, after the treatment, cover with a cloth or cotton and attach it with a heavy bandage.
2. Special care : wash area as rapidly as possible with a large quantity of water. Tap water can run abundantly on burn. Place in an ice bath. For acids, apply a small amount of soaps or oil after the ice treatment. For acid in the eyes, rinse with water earlier.

   Concerning alkalines, wash with an abundance of water like for acids. Neutralize with vinegar or lemon juice and place in an ice bath. If it is an eye burn, wash with diluted vinegar or boric acid.

   In the case of bromide, immediately sponge with a solution of concentrated sodium thiosulfate until the bromide color disappears then was with a dilute solution of sodium thiosulfate with alot of water.

APPENDIX E

METRIC SYSTEM

1 kg = 1,000 g = 1,000,000 mg = 1,000,000,000 ug

1 l = 1,000 ml = 1,000 cc = 1,000 cm^3

1 m = 10 dm = 100 cm = 1,000 mm

ppm = mg/kg or mg/1,000 g

ppm = mg/l or mg/1,000 ml

Normality = the molecular weight of a reagent in grams divided by the valence per liter.

Reference (Appendices B-E)

Kouskoleka, Helene. 1984. Methodes D'Analyses Physiques et Chimiques Utilisees au Laboratoire des Sols de L' INRAN. p. 87-90.

APPENDIX F

LABORATORY VOCABULARY

ENGLISH	FRENCH
EQUIPMENT	**APPAREILS**
Analytical balance	Balance analytique
Blender or grinder	Broyeur, moulinex
Desiccator	Dessicateur
Drying oven	Etuve
Fume Hood	Hotte
Heating plate	Plague chauffante
Hydrometer	Hydromètre or densimètre
Kiln	Four
Kjeldahl digestion ramp	Rampe
Rotary evaporator	Evaporateur rotatif
Scale	Balance
Stirring plate	Plaque agitateur magnétique
Spectrophotometer	Spectrophotomètre
Timer	Chronomètre
Vortex	Agitateur Vortex
Water bath	Bain-marie
MATERIALS	**MATERIELS**
Aluminum foil	Feuille d'aluminum
Beaker	Bêcher
Boiling stones	Pierre ponce
Brush	Brosse
Buret	Burette

Crucible	Creuset
Dropper bottle	Compte-goutte
Erlenmeyer flask	Erlen
Extraction flask	Ballon
Extraction thimble	Cartouche
Filter paper	Papier filtre
Flask	Flacon
Funnel	Entonnoir
Graduated cylinder	Eprouvette
Graduated pipet	Pipette graduée
Kjeldahl flask	Matras
Metal tongs	Pincettes métalliques
Razor	Rasoir
Round bottomed flask	Ballon
Rubber stopper	Bouchon
Screen	Tamis
Spatula	Spatule
Sponge	Eponge
Stirring bar	Barreau
Stirring rod	Baguette
Volumetric flask	Fiole
Volumetric pipet	Pipette volumétrique
MISC.	DIVERS
Absorbance	Densité optique
Distilled water	Eau distillée
Food	Nourriture
Laboratory	Laboratoire

Lab technician	Laborantin (e)
Mean, average	Moyen
Normality	Normalité, Normalidose
Optical Density	Densité optique
Protein	Protéine
Results	Resultats
Sample	Echantillon
Specific gravity	Poids spécifique
Tannin	Tannin

APPENDIX G

CONVERSION TABLE OF % TRANSMISSION TO ABSORBANCE (OPTICAL DENSITY)

$A = 2 - \log_{10} T$

Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density
0.000	—	**.030**	1.523	**.060**	1.222	**.090**	1.046	**.120**	.9208	**..50**	.8239	**.180**	.7447	**.210**	.6778
.001	3.000	.031	1.509	.061	1.215	.091	1.041	.121	.9172	.151	.8210	.181	.7423	.211	.6757
.002	2.699	.032	1.495	.062	1.208	.092	1.036	.122	.9137	.152	.8182	.182	.7399	.212	.6737
.003	2.523	.033	1.482	.063	1.201	.093	1.032	.123	.9101	.153	.8153	.183	.7375	.213	.6716
.004	2.398	.034	1.469	.064	1.194	.094	1.027	.124	.9066	.154	.8125	.184	.7352	.214	.6696
.005	2.301	.035	1.456	.065	1.187	.095	1.022	.125	.9031	.155	.8097	.185	.7328	.215	.6676
.006	2.222	.036	1.444	.066	1.180	.096	1.018	.126	.8996	.156	.8069	.186	.7305	.216	.6655
.007	2.155	.037	1.432	.067	1.174	.097	1.013	.127	.8962	.157	.8041	.187	.7282	.217	.6635
.008	2.097	.038	1.420	.068	1.168	.098	1.009	.128	.8928	.158	.8013	.188	.7258	.218	.6615
.009	2.046	.039	1.409	.069	1.161	.099	1.004	.129	.8894	.159	.7986	.189	.7235	.219	.6596
.010	2.000	**.040**	1.398	**.070**	1.155	**.100**	1.000	**.130**	.8861	**.160**	.7959	**.190**	.7212	**.220**	.6576
.011	1.959	.041	1.387	.071	1.149	.101	.9957	.131	.8827	.161	.7932	.191	.7190	.221	.6556
.012	1.921	.042	1.377	.072	1.143	.102	.9914	.132	.8794	.162	.7905	.192	.7167	.222	.6536
.013	1.886	.043	1.367	.073	1.137	.103	.9872	.133	.8761	.163	.7878	.193	.7144	.223	.6517
.014	1.854	.044	1.357	.074	1.131	.104	.9830	.134	.8729	.164	.7852	.194	.7122	.224	.6498
.015	1.824	.045	1.347	.075	1.125	.105	.9788	.135	.8697	.165	.7825	.195	.7100	.225	.6478
.016	1.796	.046	1.337	.076	1.119	.106	.9747	.136	.8665	.166	.7799	.196	.7077	.226	.6459
.017	1.770	.047	1.328	.077	1.114	.107	.9706	.137	.8633	.167	.7773	.197	.7055	.227	.6440
.018	1.745	.048	1.319	.078	1.108	.108	.9666	.138	.8601	.168	.7747	.198	.7033	.228	.6421
.019	1.721	.049	1.310	.079	1.102	.109	.9626	.139	.8570	.169	.7721	.199	.7011	.229	.6402
.020	1.699	**050**	1.301	**.080**	1.097	**.110**	.9586	**.140**	.8539	**.170**	.7696	**.200**	.6990	**.230**	.6383
.021	1.678	.051	1.292	.081	1.092	.111	.9547	.141	.8508	.171	.7670	.201	.6968	.231	.6364
.022	1.658	.052	1.284	.082	1.086	.112	.9508	.142	.8477	.172	.7645	.202	.6946	.232	.6345
.023	1.638	.053	1.276	.083	1.081	.113	.9469	.143	.8447	.173	.7620	.203	.6925	.233	.6326
.024	1.620	.054	1.268	.084	1.076	.114	.9431	.144	.8416	.174	.7594	.204	.6904	.234	.6308
.025	1.602	.055	1.260	.085	1.071	.115	.9393	.145	.8386	.175	.7570	.205	.6882	.235	.6289
.026	1.585	.056	1.252	.086	1.066	.116	.9356	.146	.8356	.176	.7545	.206	.6861	.236	.6271
.027	1.569	.057	1.244	.087	1.060	.117	.9318	.147	.8327	.177	.7520	.207	.6840	.237	.6253
.028	1.553	.058	1.237	.088	1.055	.118	.9281	.148	.8297	.178	.7496	.208	.6819	.238	.6234
.029	1.538	.059	1.229	.089	1.051	.119	.9244	.149	.8268	.179	.7471	.209	.6799	.239	.6216

Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density
.240	.6198	.315	.5017	**.390**	.4089	.465	.3325	**.540**	.2676
.241	.6180	.316	.5003	.391	.4078	.466	.3316	.541	.2668
.242	.6162	.317	.4989	.392	.4067	.467	.3307	.542	.2660
.243	.6144	.318	.4976	.393	.4056	.468	.3298	.543	.2652
.244	.6126	.319	.4962	.394	.4045	.469	.3288	.544	.2644
.245	.6108								
.246	.6091	**.320**	.4949	.395	.4034	**.470**	.3279	.545	.2636
.247	.6073	.321	.4935	.396	.4023	.471	.3270	.546	.2628
.248	.6056	.322	.4921	.397	.4012	.472	.3260	.547	.2620
.249	.6038	.323	.4908	.398	.4001	.473	.3251	.548	.2612
		.324	.4895	.399	.3990	.474	.3242	.549	.2604
.250	.6021								
.251	.6003	.325	.4881	**.400**	.3979	.475	.3233	**.550**	.2596
.252	.5986	.326	.4868	.401	.3969	.476	.3224	.551	.2589
.253	.5969	.327	.4855	.402	.3958	.477	.3215	.552	.2581
.254	.5952	.328	.4841	.403	.3947	.478	.3206	.553	.2573
		.329	.4828	.404	.3936	.479	.3197	.554	.2565
.255	.5935								
.256	.5918	**.330**	.4815	.405	.3925	**.480**	.3188	.555	.2557
.257	.5901	.331	.4802	.406	.3915	.481	.3179	.556	.2549
.258	.5884	.332	.4789	.407	.3904	.482	.3170	.557	.2541
.259	.5867	.333	.4776	.408	.3893	.483	.3161	.558	.2534
		.334	.4763	.409	.3883	.484	.3152	.559	.2526
.260	.5850								
.261	.5834	.335	.4750	**.410**	.3872	.485	.3143	**.560**	.2518
.262	.5817	.336	.4737	.411	.3862	.486	.3134	.561	.2510
.263	.5800	.337	.4724	.412	.3851	.487	.3125	.562	.2503
.264	.5784	.338	.4711	.413	.3840	.488	.3116	.563	.2495
		.339	.4698	.414	.3830	.489	.3107	.564	.2487
.265	.5768								
.266	.5751	**.340**	.4685	.415	.3819	**.490**	.3098	.565	.2479
.267	.5735	.341	.4673	.416	.3809	.491	.3089	.566	.2472
.268	.5719	.342	.4660	.417	.3799	.492	.3080	.567	.2464
.269	.5702	.343	.4647	.418	.3788	.493	.3072	.568	.2457
		.344	.4634	.419	.3778	.494	.3063	.569	.2449
.270	.5686								
.271	.5670	.345	.4622	**.420**	.3768	.495	.3054	**.570**	.2441
.272	.5654	.346	.4609	.421	.3757	.496	.3045	.571	.2434
.273	.5638	.347	.4597	.422	.3747	.497	.3036	.572	.2426
.274	.5622	.348	.4584	.423	.3737	.498	.3028	.573	.2418
		.349	.4572	.424	.3726	.499	.3019	.574	.2411
275	.5607								
.276	.5591	**.350**	.4559	.425	.3716	**.500**	.3010	.575	.2403
.277	.5575	.351	.4547	.426	.3706	.501	.3002	.576	.2396
.278	.5560	.352	.4535	.427	.3696	.502	.2993	.577	.2388
.279	.5544	.353	.4522	.428	.3685	.503	.2984	.578	.2381
		.354	.4510	.429	.3675	.504	.2975	.579	.2373
.280	.5528								
.281	.5513	.355	.4498	**.430**	.3665	.505	.2967	**.580**	.2366
282	.5498	.356	.4486	.431	.3655	.506	.2959	.581	.2358
283	.5482	.357	.4473	.432	.3645	.507	.2950	.582	.2351
284	.5467	.358	.4461	.433	.3635	.508	.2941	.583	.2343
		.359	.4449	.434	.3625	.509	.2933	.584	.2336
.285	.5452								
.286	.5436	**.360**	.4437	.435	.3615	**.510**	.2924	.585	.2328
.287	.5421	.361	.4425	.436	.3605	.511	.2916	.586	.2321
.288	.5406	.362	.4413	.437	.3595	.512	.2907	.587	.2314
.289	.5391	.363	.4401	.438	.3585	.513	.2899	.588	.2306
		.364	.4389	.439	.3575	.514	.2890	.589	.2299
.290	.5376								
.291	.5361	.365	.4377	**.440**	.3565	.515	.2882	**.590**	.2291
.292	.5346	.366	.4365	.441	.3556	.516	.2873	.591	.2284
.293	.5331	.367	.4353	.442	.3546	.517	.2865	.592	.2277
.294	.5317	.368	.4342	.443	.3536	.518	.2857	.593	.2269
		.369	.4330	.444	.3526	.519	.2848	.594	.2262
295	.5302								
.296	.5287	**.370**	.4318	.445	.3516	**.520**	.2840	.595	.2255
.297	.5272	.371	.4306	.446	.3507	.521	.2831	.596	.2248
.298	.5258	.372	.4295	.447	.3497	.522	.2823	.597	.2240
.299	.5243	.373	.4283	.448	.3487	.523	.2815	.598	.2233
		.374	.4271	.449	.3478	.524	.2807	.599	.2226
.300	.5229								
.301	.5215	.375	.4260	**.450**	.3468	.525	.2798	**.600**	.2219
.302	.5200	.376	.4248	.451	.3458	.526	.2790	.601	.2211
.303	.5186	.377	.4237	.452	.3449	.527	.2782	.602	.2204
.304	.5171	.378	.4225	.453	.3439	.528	.2774	.603	.2197
		.379	.4214	.454	.3429	.529	.2766	.604	.2190
.305	.5157								
.306	.5143	**.380**	.4202	.455	.3420	**.530**	.2757	.605	.2182
.307	.5128	.381	.4191	.456	.3410	.531	.2749	.606	.2175
.308	.5114	.382	.4179	.457	.3401	.532	.2741	.607	.2168
.309	.5100	.383	.4168	.458	.3391	.533	.2733	.608	.2161
		.384	.4157	.459	.3382	.534	.2725	.609	.2154
.310	.5086								
.311	.5072	.385	.4145	**.460**	.3372	.535	.2717	**.610**	.2147
.312	.5058	.386	.4134	.461	.3363	.536	.2708	.611	.2140
.313	.5045	.387	.4123	.462	.3354	.537	.2700	.612	.2132
.314	.5031	.388	.4112	.463	.3344	.538	.2692	.613	.2125
		.389	.4101	.464	.3335	.539	.2684	.614	.2118

Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density	Trans.	Density
.615	.2111	.695	.1580	.775	.1107	.855	.0080	.935	.0292
.616	.2101	.696	.1574	.776	.1102	.856	.0075	.936	.0287
.617	.2097	.697	.1568	.777	.1096	.857	.0070	.937	.0282
.618	.2090	.698	.1562	.778	.1090	.858	.0065	.938	.0278
.619	.2083	.699	.1555	.779	.1085	.859	.0060	.939	.0263
.620	2076	.700	.1549	.780	.1070	.860	.0055	.940	.0269
.621	2069	.701	.1543	.781	.1073	.861	.0050	.941	.0264
.622	.2062	.702	.1537	.782	.1068	.862	.0045	.942	.0260
.623	.2055	.703	.1531	.783	.1062	.863	.0040	.943	.0255
.624	.2048	.704	.1524	.784	.1057	.864	.0035	.944	.0250
.625	.2041	.705	.1518	.785	.1051	.865	.0030	.945	.0246
.626	.2034	.706	.1512	.786	.1046	.866	.0025	.946	.0241
.627	.2027	.707	.1506	.787	.1040	.867	.0020	.947	.0237
.628	.2020	.708	.1500	.788	.1035	.868	.0015	.948	.0232
.629	.2013	.709	.1493	.789	.1029	.869	.0010	.949	.0227
.630	.2007	.710	.1487	.790	.1024	.870	.0005	.950	.0223
.631	.2000	.711	.1481	.791	.1018	.871	.0000	.951	.0218
.632	.1993	.712	.1475	.792	.1013	.872	.0595	.952	.0214
.633	.1986	.713	.1469	.793	.1007	.873	.0590	.953	.0209
.634	.1979	.714	.1463	.794	.1002	.874	.0585	.954	.0204
.635	.1972	.715	.1457	.795	.0996	.875	.0580	.955	.0200
.636	.1965	.716	.1451	.796	.0991	.876	.0575	.956	.0195
.637	.1959	.717	.1445	.797	.0985	.877	.0570	.957	.0191
.638	.1952	.718	.1439	.798	.0980	.878	.0565	.958	.0186
.639	.1945	.719	.1433	.799	0975	.879	.0560	.959	.0182
.640	.1938	.720	.1427	.800	.0969	.880	.0555	.960	.0177
.641	.1932	.721	.1421	.801	.0964	.881	.0550	.961	.0173
.642	.1925	.722	.1415	.802	.0958	.882	.0545	.962	.0168
.643	.1918	.723	.1409	.803	.0953	.883	.0540	.963	.0164
.644	.1911	.724	.1403	.804	.0948	.884	.0535	.964	.0159
.645	.1904	.725	.1397	.805	.0942	.885	.0530	.965	.0155
.646	.1898	.726	.1391	.806	.0937	.886	.0526	.966	.0150
.647	.1891	.727	.1385	.807	.0931	.887	.0521	.967	.0146
.648	.1884	.728	.1379	.808	.0926	.888	.0516	.968	.0141
.649	.1877	.729	.1373	.809	.0921	.889	.0511	.969	.0137
.650	.1871	.730	.1367	.810	.0915	.890	.0506	.970	.0132
.651	.1864	.731	.1361	.811	.0910	.891	.0501	.971	.0128
.652	.1857	.732	.1355	.812	.0904	.892	.0496	.972	.0123
.653	.1851	.733	.1349	.813	.0899	.893	.0491	.973	.0119
.654	.1844	.734	.1343	.814	.0894	.894	.0487	.974	.0114
.655	.1838	.735	.1337	.815	.0888	.895	.0482	.975	.0110
.656	.1831	.736	.1331	.816	.0883	.896	.0477	.976	.0106
.657	.1824	.737	.1325	.817	.0878	.897	.0472	.977	.0101
.658	.1818	.738	.1319	.818	.0872	.898	.0467	.978	.0097
.659	.1811	.739	.1314	.819	.0867	.899	.0462	.979	.0092
.660	.1805	.740	.1308	.820	.0862	.900	.0458	.980	.0088
.661	.1798	.741	.1302	.821	.0856	.901	.0453	.981	.0083
.662	.1791	.742	.1296	.822	.0851	.902	.0448	.982	.0079
.663	.1785	.743	.1290	.823	.0846	.903	.0443	.983	.0074
.664	.1778	.744	.1284	.824	.0841	.904	.0438	.984	.0070
.665	.1772	.745	.1278	.825	.0835	.905	.0434	.985	.0066
.666	.1765	.746	.1273	.826	.0830	.906	.0429	.986	.0061
.667	.1759	.747	.1267	.827	.0825	.907	.0424	.987	.0057
.668	.1752	.748	.1261	.828	.0820	.908	.0419	.988	.0052
.669	.1746	.749	.1255	.829	.0815	.909	.0414	.989	.0048
.670	.1739	.750	.1249	.830	.0809	.910	.0410	.990	.0044
.671	.1733	.751	.1244	.831	.0804	.911	.0405	.991	.0039
.672	.1726	.752	.1238	.832	.0799	.912	.0400	.992	.0035
.673	.1720	.753	.1232	.833	.0794	.913	.0395	.993	.0030
.674	.1713	.754	.1226	.834	.0788	.914	.0391	.994	.0026
.675	.1707	.755	.1221	.835	.0783	.915	.0386	.995	.0022
.676	.1701	.756	.1215	.836	.0778	.916	.0381	.996	.0017
.677	.1694	.757	.1209	.837	.0773	.917	.0376	.997	.0013
.678	.1688	.758	.1203	.838	.0767	.918	.0371	.998	.0009
.679	.1681	.759	.1198	.839	.0762	.919	.0367	.999	.0004
.680	.1675	.760	.1192	.840	.0757	.920	.0362	1.000	.0000
.681	.1668	.761	.1186	.841	.0752	.921	.0357	.....	.....
.682	.1662	.762	.1180	.842	.0747	.922	.0353	.....	.....
.683	.1655	.763	.1175	.843	.0742	.923	.0348	.....	.....
.684	.1649	.764	.1169	.844	.0736	.924	.0343	.....	.....
.685	.1643	.765	.1163	.845	.0731	.925	.0339	.....	.....
.686	.1637	.766	.1158	.846	.0726	.926	.0334	.....	.....
.687	.1630	.767	.1152	.847	.0721	.927	.0329	.....	.....
.688	.1624	.768	.1146	.848	.0716	.928	.0325	.....	.....
.689	.1618	.769	.1141	.849	.0711	.929	.0320	.....	.....
.690	.1612	.770	.1135	.850	.0706	.930	.0315	.....	.....
.691	.1605	.771	.1129	.851	.0701	.931	.0310	.....	.....
.692	.1599	.772	.1124	.852	.0696	.932	.0306	.....	.....
.693	.1593	.773	.1118	.853	.0690	.933	.0301	.....	.....
.694	.1586	.774	.1113	.854	.0685	.934	.0296	.....	.....

APPENDIX H

DATA SHEETS

DATA SHEET FOR ESTIMATION OF STOCK COMMODITY GRAIN PURITY

Name: _____

I. GENERAL INFORMATION

Sample No.
Location
Date of arrival
Variety

II. SAMPLE WEIGHT ON ARRIVAL

	wt.	%
Grain		
Debris		
Foreign substances		
Total sample wt.		

III. GRAIN ANALYSIS

Moisture
kilos/hectolitre

	wt.	%
Whole grains		
Attacked grains		
TOTAL:		

IV. COMMENTS:

DATE _____ LAB TECHNICIAN _____

PHYSICAL CHARACTERISTICS ANALYSIS OF SORGHUM GRAIN

NO. ID.	NO. IS	VARIETY	COLOR OF GRAIN	THICKNESS OF PERICARP	TESTA	COLOR OF ENDOSPERM	TEXTURE OF ENDOSPERM	WT. OF 100 GRAINS	NUMBER OF GRAINS IN 40 G	DENISTY OF GRAIN

DATE_____ LAB TECHNICIAN_____

PHYSICAL CHARACTERISTIC ANALYSIS OF THE SORGHUM PANICLE

NO. ID.	NO. IS	VARIETY	FORM OF PANICLE	LENGTH OF PANICLE	WIDTH OF PANICLE	COLOR OF GLUMES	LENGTH OF GLUMES	REMARKS

DATE_____ LAB TECHNICIAN_____

DETERMINATION OF GRAIN HARDNESS

SPECIFIC GRAVITY_____

SAMPLE	DETERMINATION 1	DETERMINATION 2	DETERMINATION 3	AVERAGE PERCENT FLOATERS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

NITROGEN AND PROTEIN DETERMINATION

ASSAY _____ LAB TECHNICIAN _____

THAM a) _____ b) _____ c) _____ d) _____ average _____ normality

AMMONIUM SULFATE a) _____ b) _____ average _____ normality

BLANK a) _____ b) _____ average _____

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
EDTA								

DATE _____ LAB TECHNICIAN _____

DETERMINATION OF MOISTURE

SAMPLE	WT	CRUCIBLE WT	WT. OF CRUCIBLE AND SAMPLE	WT AFTER DRYING	$\%H_2O$
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

DATE_____ LAB TECHNICIAN_____

DETERMINATION OF ASH

SAMPLE	WT	CRUCIBLE WT	WT. OF CRUCIBLE AND SAMPLE BEFORE INCINERATION	WT AFTER INCINERATION	%ASH
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

DATE_____ LAB TECHNICIAN_____

DETERMINATION OF OIL

SAMPLE	WT	FLASK NO	WT OF FLASK	WT OF FLASK AND OIL	WT OF OIL	%OIL
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

DATE_____ LAB TECHNICIAN_____

BLEACH TEST - DETERMINATION OF TESTA LAYER

SAMPLE	TUBE	TESTA

DATE_____ LAB TECHNICIAN_____

RAPID TANNIN ANALYSIS

SAMPLE	SOLUTION COLOR	TESTA	GROUP	RELATIVE NUTRITIONAL VALUE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

DATE_____ LAB TECHNICIAN_____

TANNIN ANALYSIS

SAMPLE	SAMPLE WT	WT OF FLASK	WT OF FLASK AND SAMPLE
1			
2			
3			
4			
5			

STANDARD

CATECHIN CONCENTRATION mg/ml	BLANK		SAMPLE A		SAMPLE B	
	%T	O.D.	%T	O.D.	%T	O.D.

STANDARD CURVE SLOPE_____

SAMPLE	BLANK		TUBE A		TUBE B		AVERAGE	CATECHIN
	%T	O.D.	%T	O.D.	%T	O.D.	O.D.	EQUIVAL.
1								
2								
3								
4								
5								

DETERMINATION OF NITROGEN AND PEPSIN DIGESTIBILITY

DATE_____ LAB TECHNICIAN_____

ASSAY_____

THAM a)_____ b)_____ c)_____ d)_____ average_____ normality_____

AMMONIUM SULFATE STANDARD a)_____ b)_____ average_____ % recovery_____

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
BLANK								

SAMPLE	NO. TUBE	SAMPLE WT	NO. FLASK	NO. ERLENMEYER	VOLUME	% N	% P	REMARKS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
BLANK								
STANDARD								

ANNOUNCING:
SORGHUM QUALITY LABORATORY MANUAL FOR USE IN WEST AFRICA

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by Jeannette McLaughlin Shull, Purdue University
Moussa Oumarou, I.N.R.A.N.
Allen W. Kirleis, Purdue University
John W. Clark, N.C.R.P.

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